CHAPTER 2. PART 29
AIRWORTHINESS STANDARDS
TRANSPORT CATEGORY ROTORCRAFT

SUBPART C - STRENGTH REQUIREMENTS

GENERAL

AC 29.301. § 29.301 LOADS.

a. Explanation.

(1) The rule is a general statement concerning limit and ultimate loads and the application of these loads to the rotorcraft.

(2) Ultimate loads are limit loads multiplied by the prescribed factors of safety.

(3) The specified loads must be distributed appropriately or conservatively and significant changes in distribution of the loads, as a result of deflection, must be taken into account.

b. Procedures. The design criteria report and/or design loads report must contain data that comply with the rule.

AC 29.303. § 29.303 FACTOR OF SAFETY.

a. Explanation.

(1) Unless otherwise provided by FAR Part 29, a factor of safety of 1.5 is required and is applied as stated in the rule. This safety margin will assure that the design strength of the rotorcraft is greater than the design loads contained in FAR Part 29.

(2) Other rules, §§ 29.561(b)(3) and 29.787(c), specify use of defined ultimate inertia forces for protection of occupants.

b. Procedures.

(1) The design criteria report and/or design loads report must contain data that include the appropriate factor of safety.

(2) The factor of safety multiplies the limit external and inertia loads. The rule does allow the application of this factor to the resulting “limit internal” stresses if it is more conservative.

AC 29.305. <u>§ 29.305 STRENGTH AND DEFORMATION</u>.

a. <u>Explanation</u>.

(1) This general rule defines, in relative terms, allowable deformation for limit and ultimate loads.

(2) If static tests are used to show compliance with this rule, the structure must support ultimate loads for 3 seconds without failure. Alternatively, dynamic tests simulating actual load applications may be used.

(3) Section 29.307 concerns proof of the structure and requires certain specified tests. This rule also allows substantiation by structural analysis. See paragraph AC 29.307.

b. <u>Procedures</u>. Any test results, static or dynamic, must satisfy the limitations or acceptance criteria contained in the rule.

(1) Any test proposals submitted for approval that are used to demonstrate compliance with sections of FAR Part 29 must contain the criteria stated in the rule.

(2) Any test results reports must contain data and information showing the test results comply with the standard.

(3) When dynamic tests are not used to substantiate the ultimate strength of structure subject to significant dynamic response under load, the analytical substantiation should consider flexibility effects and rate of load application (tail boom strength under landing loads is an example of a strength which needs dynamic amplification effects considered).

AC 29.307. <u>§ 29.307 (Amendment 29-4) PROOF OF STRUCTURE</u>.

a. <u>Explanation</u>.

(1) The rule requires compliance for each critical loading condition. Certain tests must be conducted as specified. Additional tests for new or unusual design features may be required as noted in § 29.307(b)(6).

(2) "Structural analysis may be used only if the structure conforms to those for which experience has shown the structural analysis method to be reliable."

(3) Fatigue substantiation requirements are explained further in paragraph AC 29.571.

b. <u>Procedures.</u>

(1) The design criteria and/or design loads report should contain typical or representative loading conditions from which the critical loading conditions will be selected for analytical substantiation in structural (static and fatigue) reports and dynamics (vibration and stability) reports and fatigue, static, dynamic, or operational test reports.

(2) Whenever tests are used or required, a test proposal or plan must be approved prior to the tests. The test article must have received conformity inspections and must have been accepted by the FAA/AUTHORITY for the test. Test fixtures and instrumentation must also be acceptable to the FAA/AUTHORITY (using DERs as appropriate) prior to the start of the test. The quality control office of the applicant or other qualified personnel may be authorized to conduct inspections of the test fixtures and instrumentation rather than the FAA/AUTHORITY or DER performing this task. The test proposal may be used to define and to authorize the means to accomplish inspection of the test fixtures and instrumentation. Unnecessary drawings, such as test fixture details, or layering of approvals is not intended or envisaged by this policy. Drawings, sketches, or photographs have been used by the FAA/AUTHORITY to control and to assure correct location, direction, and magnitude of loads and other critical test parameters.

(3) Structural analysis has been accepted for rotorcraft in place of static tests. Generally the rotorcraft airframe should have frequency placements remote to predominate rotor excitation sources, including rotor harmonics, to avoid undesirable and possibly excessive vibration and potentially high operating stress levels due to this vibration. During the flight load measurement program conducted under § 29.571, critical loaded areas or critical joints may be instrumented with strain gages or other stress strain measuring devices. This actual flight data may be compared to the analytical data to verify accuracy.

(4) Section 29.307(b) specifies certain tests. Test proposals must be approved prior to conducting official FAA/AUTHORITY tests. Other paragraphs in this advisory circular pertain to those tests.

AC 29.307A. § 29.307 (Amendment 29-30) PROOF OF STRUCTURE.

a. Explanation. Amendment 29-30 adds the requirement to account for the environment to which the structure will be exposed in operation. This change is intended to codify recent FAA/AUTHORITY and industry practices for the consideration of environmental effects in showing “proof of structure.”

b. Procedures. All of the policy material pertaining to this section remains in effect with the following additions:

(1) For either tests or an analysis, environmental effects are now explicitly required. Consideration of loss of strength and stiffness of metals with elevated temperatures and loss of strength and stiffness of composite materials from exposure

to heat, moisture, or other operational environments is now required and should be documented in analyses and test reports.

(2) MIL-HDBK-5F, AC 20-107B, or MIL-HDBK-17B, Vol I, Rev. 1E; Vol. II, Rev. D; Vol. III, Rev. E (or later versions) are acceptable sources of data and procedures to show compliance with environmental effects of metallic and composite materials, respectively.

AC 29.309. § 29.309 DESIGN LIMITATIONS.

a. Explanation.

(1) The rule requires an orderly selection and presentation of the basic structural design limitations of the rotorcraft. The applicant must establish these structural limitations to facilitate design of the rotorcraft.

(2) Refer to the rule for the specific requirements.

b. Procedures.

(1) The design criteria and/or design load report should contain the design limits specified.

(2) These items are structural design limits. Other requirements may result in narrowing the ranges of type design limits or in reducing limits. It is not necessary to revise structural design criteria limits to agree with more conservative operational limits established during the certification program. The operational limits may be subsequently expanded by additional flight tests to agree with design limits.

SUBPART C - STRENGTH REQUIREMENTS

FLIGHT LOADS

AC 29.321. § 29.321 GENERAL - FLIGHT LOADS.

a. Explanation.

(1) The rule specifies the way the loads will be applied to the rotorcraft. It requires load analysis from minimum to maximum design weight. Any practical distribution of disposable loads must be included in the analysis.

(2) Paragraph (a) of the rule states: "The flight load factor must be assumed to act normal to the longitudinal axis of the rotorcraft and to be equal in magnitude and opposite in direction to the rotorcraft inertia load factor at the center of gravity."

b. Procedures.

(1) Derivation of the flight loads is required by and specified in § 29.337 through § 29.351. This rule requires flight load determination from minimum to maximum weight and for disposable loads.

(2) The application of the design loads derived from the flight load factor will be as specified. The flight loads analysis data must comply with the rule.

AC 29.337. § 29.337 (Amendment 29-30) LIMIT MANEUVERING LOAD FACTOR.

a. Explanation. The rotorcraft must be designed and substantiated to load factors as specified to provide a minimum level of structural integrity of the rotorcraft airframe and rotors.

(1) A range of design positive load factors from +3.5 to +2.0 may be used.

(2) A range of design negative load factors from -1.0 to -0.5 may be used.

(3) Load factors inside the range of +3.5 to -1.0 may be used provided the probability of exceeding the design load factors is shown by analysis and flight tests to be extremely remote, and the selected load factors are appropriate to each weight condition between design maximum and minimum weights.

(4) Load factors exceeding these "minimums" may be used.

b. Procedures.

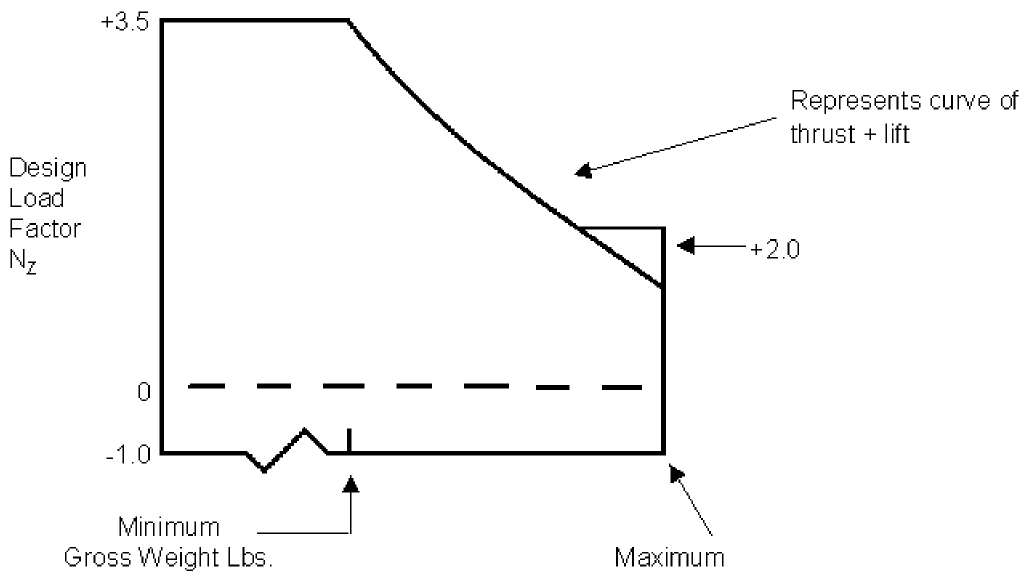
(1) The applicant may elect to substantiate the rotorcraft for a design maneuvering load factor less than +3.5 and more than -1.0. Whenever this option is used, an analytical study and flight demonstration are required.

(i) The maximum positive design load factor is +3.5 generally at a weight below maximum gross weight. The <u>maximum</u> thrust capability of the main rotor combined with incremental lift of wings or sponsons, if installed, results in a maximum design positive load factor. An example of a load factor - gross weight curve is shown in figure AC 29.337-1. Note the minimum positive design load factor is +2.0 even though the required analysis and flight demonstration may prove the rotorcraft is not capable of achieving this load factor. This curve also illustrates compliance with § 29.337(b)(2) since the design load factor varies with gross weight.

(ii) The largest negative design load factor is -1.0; however, several current rotorcraft designs are not capable of achieving a negative load factor. Therefore, -0.5 has been an acceptable structural design negative load factor for certain rotorcraft designs.

(2) Whenever the applicant analytically substantiates the lower load factors allowed by § 29.337(b), the applicant must conduct the flight demonstration required by § 29.337(b)(1). The flight test personnel must determine that the demonstration is conducted in a manner to show that the probability of exceeding the selected design load factors, (those factors less than +3.5 and more than -1.0) is extremely remote. (See Order 8110.4, paragraph 166c(2)(c)).

(3) A numerical value has not been assigned to “extremely remote” in this standard.



LOAD FACTOR GROSS WEIGHT CURVE
FIGURE AC 29.337-1

AC 29.339. § 29.339 RESULTANT LIMIT MANEUVERING LOADS.

a. Explanation. The rule specifies or defines the application of rotor and lift surface loads to the rotorcraft.

(1) The design maneuvering load factors required by § 29.337 will result in or be derived from rotor thrust or lift and from auxiliary surface lift.

(2) The rules §§ 29.321, 29.337, 29.341, and 29.351 all complement one another and result in the derivation of design flight loads that will be imposed to assure structural integrity of the rotorcraft.

(3) The following assumptions and conditions are specified in the rule.

(i) The rule requires application of appropriate loads at each rotor hub and auxiliary lifting surface.

(ii) Power-on and power-off flight with maximum design rotor tip speed ratio and specific conditions that must be considered.

(iii) Rotor tip speed ratio, defined in the rule, has been carried forward from the initial rotorcraft certification rules issued in 1946. The rotor tip speed ratio is a basic parameter used in calculating rotor aerodynamic forces.

b. Procedures.

(1) The rule specifies an acceptable assumption concerning application of the rotorcraft maneuvering loads.

(2) The rotor tip speed ratio is a parameter found in textbooks and other books such as NACA Report No. 716. The equation in the rule contains angle, “a.” Report No. 716 also defines angle, “a,” as the angle of attack of the rotor disk. This definition is more easily understood than the definition contained in the rule.

(3) The rotorcraft design loads are derived as prescribed by §§ 29.321, 29.337, 29.341, and 29.351. These loads are applied to the rotor or rotors and any auxiliary surface as prescribed by this rule.

AC 29.341. §29.341 GUST LOADS.

a. Explanation.

(1) The rotorcraft must be substantiated for the loads derived from 30 feet per second vertical and horizontal gusts from hovering to 1.11 V_{NE} ; i.e., (V_D).

(2) Gust loads for any vertical stabilizing surface should be derived for lateral or sideward gusts, as well as the head-on horizontal gusts. See paragraph AC 29.413, § 29.413(a)(2).

(3) Gust loads for any horizontal stabilizing surface should be derived for vertical gusts, upward and downward, as well as for head-on gusts. See paragraph AC 29.413.

b. Procedures.

(1) Either sharp-edged (instantaneous) gusts or sharp-edged gusts modified by an alleviation (attenuation) factor may be used for calculating aerodynamic loads for the rotorcraft and any installed stabilizing surfaces. The following conditions may be used:

(i) Vertical gusts may be considered normal to the flight path of the rotorcraft except during hover or low speed flight (20 knots or less) when the gusts may be assumed normal to the longitudinal axis of the rotorcraft.

(ii) For a vertical stabilizing surface, the horizontal gusts are normal to the flight path of the rotorcraft except during hover or low speed flight when the gusts may be assumed normal to the longitudinal axis of the rotorcraft.

(iii) A primary effect of encountering the gust is to change the lift of the rotors and rotorcraft surfaces. Of primary concern is the gust load or lift created by the main rotor or rotors. The lift increment of the horizontal stabilizing surface and fuselage are generally negligible when compared to the rotor and may be neglected for the rotorcraft gust load determination if proven negligible by analysis.

(iv) The rotorcraft shall be assumed in stabilized level flight prior to meeting the gust.

(v) The gust velocity may be assumed uniform across the rotorcraft.

(vi) Gust loads on the stabilizing surfaces are required as stated in paragraph AC 29.413.

(2) The rotorcraft design maneuvering load factors may generally exceed the design gust load factors calculated in compliance with this rule. This may be attributed to the small incremental change in lift due to the 30 FPS gust. Nonetheless, design gust loads for the rotorcraft shall be calculated as specified in the rule to assure the rotorcraft maneuvering load factors do, in each case, exceed the design gust load factor.

(3) For further information about rotorcraft gust response characteristics, see Paper No. 9 presented at the AHS/NASA - Ames Specialist's Meeting on Rotorcraft Dynamics, February 13-15, 1974. The paper, entitled, "Helicopter Gust Response

Characteristics Including Unsteady Aerodynamics Stall Effects," was written by P.J. Arcidiacono, R.R. Berquist, and W.T. Alexander, Jr. References listed in the paper may be helpful also.

AC 29.351. § 29.351 YAWING CONDITIONS.

a. Explanation. The rule requires proof of a rotorcraft "structural" yaw or sideslip design envelope. This sideslip envelope must cover minimum forward speed or hover to V_H or V_{NE} , whichever is less. The rotorcraft must be structurally safe for the thrust capability of the directional control system.

(1) The rotorcraft structure must be designed to withstand the loads for the specified yaw conditions. The standard does not require a structural flight demonstration. It is a structural design standard.

(2) Maximum displacement of the directional control, except as limited by pilot effort (130 pounds; § 29.397(a)), is required for the conditions cited in the rule. A control system rate limiter or a yaw damper may be used. The total displacement is therefore a function of time as well as the maximum effort applied (130 pounds).

(i) At low airspeeds, 90° yaw (sideward flight) should be the design limit.

(ii) At high airspeeds, stabilized yaw angle (stabilized sideslip) must be substantiated as stated in the rule.

(iii) At high airspeeds, the maximum tail rotor thrust will be combined with the vertical (directional) stabilizer surface load, if a stabilizer is used, as specified by § 29.351(b)(1).

(iv) At high airspeeds, while the rotorcraft is in the sideslip condition, the directional control is then returned to the neutral position, attendant with the flight condition. The tail rotor thrust will be added to the restoring force of the vertical stabilizer.

(v) Both right and left yaw conditions should be proven.

(3) The tail rotor attachment structure must comply with § 29.403.

(4) The vertical stabilizing surface must also comply with § 29.413.

b. Procedures.

(1) Many of the current single main rotor rotorcraft designs have vertical (directional) stabilizing surfaces. These surfaces may be solely vertical stabilizing fins as on the Bell Model 206, or a swept vertical extension of the tail boom as on the Hiller

Model FH1100. The Hiller FH1100 tail surface houses the tail rotor drive shaft and the tail rotor output gearbox.

(i) For vertical stabilizers, the airloads may be assumed independent of the tail rotor thrust.

(ii) For vertical stabilizers that house the tail rotor output gearbox, such as the Hiller Model FH1100, the tail surface air loads will add to or subtract from the tail rotor thrust according to the flight condition under consideration.

NOTE: For one example: At stabilized yaw to the right (left pedal depressed to limit) (§ 29.351(b)(2)), the tail rotor thrust moment should equal the restoring moment of the tail boom, vertical stabilizer and main rotor torque. As stated by § 29.351(b)(3), the tail rotor thrust moment then is added to the vertical stabilizer restoring moment. The addition of tail rotor thrust (§ 29.351(b)(3)) and vertical stabilizer load is generally one of the critical design conditions for the fuselage/tail boom.

(iii) For vertical stabilizers or fins that have an offset incidence angle with respect to the rotorcraft axis, the vertical fin moment is added, or subtracted as applicable, to the tail rotor thrust moment. The condition stated in § 29.351(b)(1) may result in adding the fin load to the tail rotor thrust.

(iv) Low airspeed maneuvers, such as sideward, rearward, and hover turns over a spot, typically impose insignificant aerodynamic loads on the fuselage and/or tail boom. The aerodynamic loads at V_H or V_{NE}, whichever is required, are generally the significant aerodynamic design loads.

(v) A rational assessment of the various yaw conditions may be used to reduce the load deviation and analysis to the critical rotorcraft design conditions.

(vi) The rotorcraft structure shall be analyzed or tested for loads derived from the critical design conditions.

(vii) A simple structural design envelope may be derived from these design data. If the right or left yaw limits are not very different, common, conservative design limits may be used. A sample yaw/forward speed diagram, as derived from design analysis of the characteristics of a hypothetical rotorcraft, is presented in figure AC 29.351-1. A table of values would also suffice. This figure reflects characteristics which include a 90° yaw when the directional control inputs are applied at low airspeeds (up to 30 knots presumably the maximum sideward flight speed of which this aircraft is capable) and 10° yaw when they are applied at V_H, with a straight line variation from 30 knot forward speed to V_H.

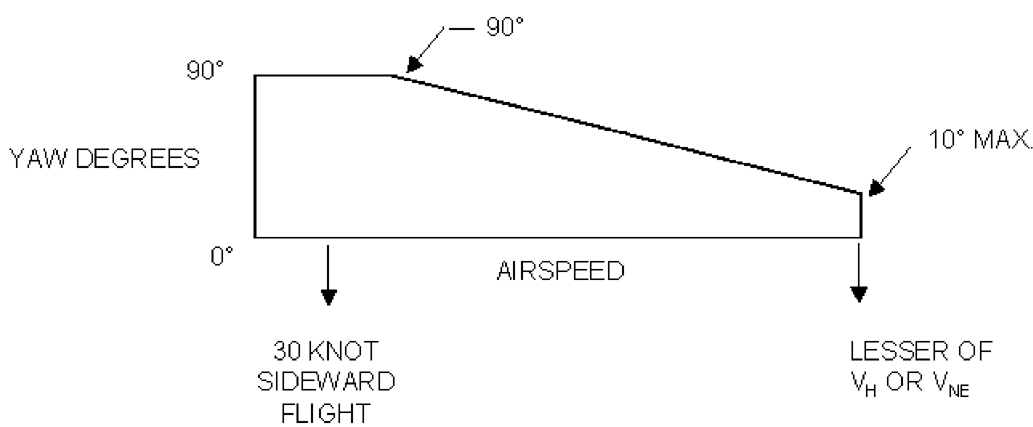


FIGURE AC 29.351-1 SAMPLE YAW/FORWARD SPEED DIAGRAM

(viii) During flight test evaluations, yaw angles have been measured using a yaw angle probe (swiveling vane type) on a nose boom. Both a visual readout for the pilot and a record, such as an oscillograph trace, have been used. This test may be conducted in the flight test program or in the flight load survey program. This record should confirm the yaw angle used in design as conservative with respect to operational and actual flight characteristics. This test is not a requirement however.

AC 29.351A. § 29.351 (Amendment 29-30) YAWING CONDITIONS.

a. Explanation. Amendment 29-30 adds maximum sideslip angles to the existing § 29.351 for structural design purposes. The standard should apply to power-on conditions; not power-off, since V_H is a part of the standard. For airspeeds up to 0.6 V_{NE}, sideslip angles larger than 90° (or sideward flight) need not be considered. For airspeeds at V_{NE} or V_H (whichever is less), sideslip angles larger than 15° need not be considered.

b. Procedures.

(1) All of the policy material pertaining to this section remains in effect with the addition of the maximum sideslip limits of 90° and 15° specified above. The rotorcraft does not need to be capable of attaining these conditions. A revised yaw/forward speed diagram is presented in figure AC 29.351-2.

(2) FAR § 29.351(b)(1) incorrectly references § 29.395(a) for maximum pilot forces. The correct reference should be § 29.397(a).

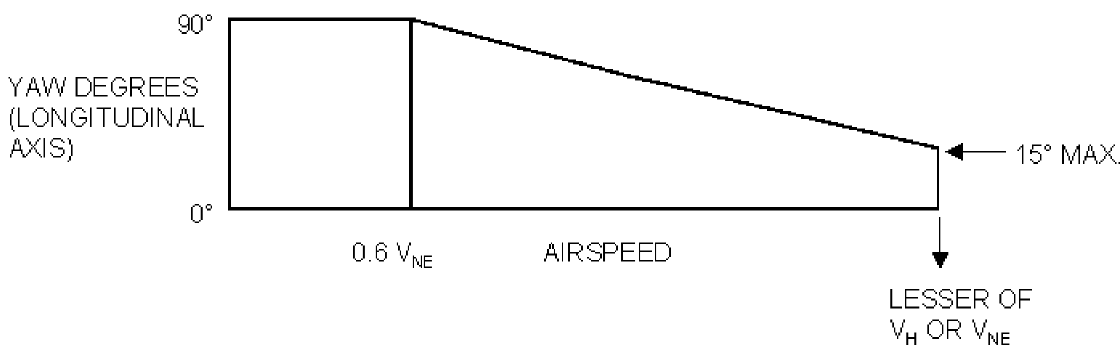


FIGURE AC 29.351-2 SAMPLE YAW/FORWARD SPEED DIAGRAM

AC 29.351B. <u>§ 29.351 (Amendment 29-40) YAWING CONDITIONS</u>.

a. <u>Explanation</u>. Amendment 29-31 deleted FAR § 29.403 and § 29.413 since the references and requirements are adequately addressed in §§ 29.337, 29.339, and 29.341. Paragraphs AC 29.403 and AC 29.413 are retained as guidance information.

b. <u>Procedures</u>. All of the policy material pertaining to this section remains in effect except for references to §§ 29.403 and 29.413 in paragraphs AC 29.351a(3) and a(4).

AC 29.361. <u>§ 29.361 (Amendment 29-26) ENGINE TORQUE</u>.

a. <u>Explanation</u>.

(1) The rotorcraft should be designed for limit engine torque values, as prescribed by the rule, to account for maximum engine torque, including certain transients and torsional oscillations. The rule recognized that reciprocating (piston) engines generate higher torque oscillations than turbine engines.

(i) A factor of 1.25 applies to maximum continuous power for turbine engines. Section 29.923 refers to torque output and § 29.927(b) refers to other torque output conditions for use in an "endurance test."

(ii) Torque factors are also specified for reciprocating engines having two or more cylinders in § 29.361(a)(2) or § 29.361(b) of Amendment 29-26. The appropriate torque factor applies to takeoff power torque as well as maximum continuous power and other power conditions.

(2) Amendment 29-26 introduced additional turbine engine installation considerations for the following:

(i) Engine torque loads associated with emergency operation of governor-controlled turboshaft engines.

(ii) Torque reaction loads from sudden turbine engine stoppage which is applied to the engine and the engine suspension and restraint system.

(3) Paragraph AC 29.549 concerns § 29.549(c) and (e) that contains design standards for engine mounts and adjacent structure for flight and landing and also flight with 2 ½-minute OEI power rating. Amendment 29-26 added OEI power to the standard.

(4) Section 29.547(e)(1)(ii) concerns the application of limit engine torque to design of the main rotor structure.

b. <u>Procedures</u>.

(1) The engine torque associated with the maximum continuous power condition should be multiplied by the appropriate torque factor to obtain the engine torque value used for structural substantiation purposes of the rotorcraft.

(2) The torque values associated with the minimum power-on RPM limit should be used. Maximum power-on speed limit will result in a lower torque value when calculating torque from design horsepower values. However, due to piston engine power output characteristics, an engine may produce a higher torque at higher engine speeds contrary to the previous statement. The torque factor should account for this characteristic.

(3) For turbine engines limit torque values are determined for the four cases cited. Two cases are related to “endurance” test standards.

(4) For sudden stoppage of turbine engines the engine manufacturer can reasonably provide engine rotating inertia and deceleration time expected in the event of sudden engine stoppage which generates these critical loads in the engine mounting and restraint system. These manufacturer’s data should be acceptable for use in complying with this part of the design standard.

SUBPART C - STRENGTH REQUIREMENTS

CONTROL SURFACE AND SYSTEM LOADS

AC 29.391. § 29.391 CONTROL SURFACE AND SYSTEM LOADS - GENERAL.

a. Explanation. This general rule concerns requirements for design loads of tail rotors, control or stabilizing surfaces, and their control system.

b. Procedures. The design criteria and/or the design loads report must contain the loads dictated by the referenced rules. See paragraphs AC 29.395, AC 29.397, AC 29.399, AC 29.401, AC 29.403, AC 29.411, and AC 29.413.

AC 29.391A. § 29.391 (Amendment 29-30) CONTROL SURFACE AND SYSTEM LOADS - GENERAL.

a. Explanation. Amendment 29-30 adds an explicit reference to § 29.427, Unsymmetrical Loads (paragraph AC 29.427), to clarify that substantiation for unsymmetrical loads is a general control surface requirement. A reference to § 29.399, Dual Control System (paragraph AC 29.399), is also added for clarification. In addition, §§ 29.401, 29.403, 29.413 were removed by this amendment since these references and requirements were adequately addressed in other standards.

b. Procedures. The referenced AC paragraphs become AC 29.395, AC 29.395A, AC 29.397, AC 29.399, AC 29.411, and AC 29.427.

AC 29.395. § 29.395 CONTROL SYSTEM.

a. Explanation. Control system design loads and the application of these loads are contained in this rule.

(1) Paragraph (a) of the rule specifies the way or means of reacting the design loads specified in §§ 29.397 and 29.399 (for dual control systems). The design loads must be imposed on any locks and stops and irreversible mechanisms in the control system. Both rotor blade horns and control surface horns must react without failure, the specified loads while the controls are in critical positions.

(2) Paragraph (b) of the rule specifies application of limit pilot forces or of the maximum loads that can be obtained in normal operation, including any single power boost system failure, whichever is greater. However, minimum limit pilot force 0.60 of the loads specified in §§ 29.397 and 29.399, may be used, as specified, in parts of the primary control system that are not stiff enough to react to the loads specified in the first part of Paragraph (b) of the rule. Note the objective for a rugged control system.

(3) Control system design feature and test requirements are found in §§ 29.671 through 29.695. Bearing factors and fitting factors are specified in §§ 29.623 and 29.625, respectively.

b. Procedures.

(1) The design criteria and/or a design loads report that includes the primary control system design loads should be submitted for FAA/AUTHORITY approval.

(2) The rotorcraft control system may be tested to ultimate design loads or may be analyzed for the ultimate design loads. See paragraph AC 29.307.

(i) It is advisable that the applicant prepare a proposal describing the procedures and techniques to be used in the static testing of the control system which reflects compliance with the condition specified. It is further advisable that the FAA/AUTHORITY concur that the tests proposed achieve that objective. Omission of these steps may result in the need for retesting. The test results should be documented.

(ii) If tests are not conducted, a structural analysis of the control system is required. Appropriate factors from §§ 29.685(e), 29.623, and 29.625 must be used as specified. A structural analysis report should be used to document compliance with § 29.685(d)(1) and (4), and § 29.685(f).

(3) If a part of the control system is not stiff or rigid enough to react the design loads specified in § 29.397, that part of the system may be substantiated for lower loads as prescribed.

(i) The limit design loads are those loads specified in § 29.397;

(ii) The limit design loads are the maximum that can be obtained in normal operation, including any single power boost system failure, except for objectives stated for a rugged system; and

(iii) In lieu of a rational analysis, the limit design loads may be 0.60 of the loads specified in § 29.397.

(iv) For example, if a control surface servo tab or a small elevator is a part of the rotorcraft design, the control system for this part must be stiff enough to react the control surface loads without failure and to provide enough surface deflection to control the rotorcraft. These limit loads may be 60 pounds fore and aft and 40 pounds laterally on the cyclic control stick in lieu of a rational analysis and may be the maximum loads that can be obtained in normal operation.

(v) If a hydraulic power actuation or boost system is part of the rotorcraft design, the design limit load for the affected parts of the control system will be the maximum output force of the boost at normal operating pressure added to the limit design loads resulting from the loads specified in § 29.397. If a single failure in the power portion of the hydraulic system results in actuator forces that exceed the maximum output force at normal operating pressure, the highest output loads must be used as noted in subparagraph (3)(ii). This hydraulic system failure standard is specified in § 29.695(a)(1) as well.

(4) Controls proof and operation test is required by §§ 29.307(b), 29.681, and 29.683. This test is conducted using the design limit loads approved under § 29.395(b). See paragraphs AC 29.681 and AC 29.683.

AC 29.395A. <u>§ 29.395 (Amendment 29-30) CONTROL SYSTEM</u>.

a. <u>Explanation</u>. Amendment 29-30 clarifies that the loads in § 29.395(b) apply to power "control" systems not just power "boost" systems; and the limit pilot forces prescribed in § 29.397 are required to be applied in conjunction with the forces from normally energized power devices. The amendment may increase required loads for systems if operational loads may be exceeded through jamming, ground gusts, control inertia, or friction. If so, the system is required to withstand 100 percent of limit pilot forces specified in § 29.397, rather than 60 percent of the limit pilot forces as specified previously.

b. <u>Procedures</u>. The procedures of paragraph AC 29.395 continue to apply except that the increased loads in new paragraph § 29.355(b)(4) of 100 percent of limit pilot forces are specified for systems where operational loads may be exceeded by jamming, ground gusts, control inertia, or friction.

AC 29.397. <u>§ 29.397 (Amendment 29-12) LIMIT PILOT FORCES AND TORQUES</u>.

a. <u>Explanation</u>. Design forces are contained in the rule.

(1) Primary controls, pilot and copilot, must be designed for the limit pilot forces specified in paragraph (a) of the rule.

(2) For other operating controls, such as flap, tab, stabilizer, rotor brake, and landing gear, design limit forces are specified in paragraph (b) of the rule.

b. <u>Procedures</u>.

(1) Design loads specified in the rule must be used in required structural tests and in any structural strength analysis of the control systems submitted in compliance with other rules.

(2) Operation tests of the control systems noted in other rules require application of these forces also.

AC 29.399. § 29.399 DUAL CONTROL SYSTEM.

a. Explanation. Design limit loads are specified for dual control systems. Pilot effort forces applied in opposition and in the same direction are required for dual control systems.

b. Procedures.

(1) Design loads specified in the rule must be used in required structural tests and in any structural strength analysis submitted for compliance with the other rules.

(2) Operation tests of the control systems, noted in other rules, require application of these forces also.

AC 29.401. § 29.401 (Amendment 29-4) AUXILIARY ROTOR ASSEMBLIES.

a. Explanation.

(1) For rotorcraft equipped with auxiliary rotors, normally called tail rotors, an endurance test is required by § 29.923 and structural strength substantiation is required. Section 29.401(b) specifically refers to structural strength substantiation for centrifugal loads resulting from maximum design rotor RPM. Due to the pitch feathering requirements, auxiliary rotors typically have detachable blades.

(2) The rotor blade structure must have sufficient strength to withstand not only aerodynamic loads generated on the blade surface, but also inertial loads arising from centrifugal, coriolis, gyroscopic, and vibratory effects produced by this blade movement. Sufficient stiffness and rigidity must be designed into the blades to prevent excessive deformation and to assure that the blades will maintain the desired aerodynamic characteristics. As a design objective, the structural strength requirements should be met with the minimum material. Excess blade weight imposes extra centrifugal loads that may increase the operating stress levels. Blade weight and strength should be optimized. Even though a structural strength analysis for the blade design loads is required, a flight load survey and fatigue analysis are also required by § 29.571.

(3) Section 29.1509 defines the design rotor speed as that providing a 5 percent margin beyond the rotor operating speed limits.

b. Procedures.

(1) The endurance tests prescribed by §§ 29.923 and 29.927 require achieving certain speeds, power, and control displacement for the auxiliary (tail) rotor as well as the main rotor. The parts must be serviceable at the conclusion of the tests.

(2) Structural substantiation of the auxiliary (tail) rotor is required to assure integrity for the minimum and maximum design rotor speeds and the maximum design rotor thrust in the positive and negative direction. Thrust capability of the rotor should offset the main rotor torque at maximum power as required by § 29.927(b).

(i) The maximum and minimum operating rotor speed, power-off, is 95 percent of the maximum design speed and is 105 percent of the minimum design speed, respectively.

(ii) The rotor operating speed limits shown during the official FAA/AUTHORITY flight tests must include the noted 5 percent margin with respect to the design speeds.

(iii) The auxiliary rotor generally has a positive and negative pitch limit that assures adequate directional control throughout the operating range of the rotorcraft. The power-off rotor speed limits are generally broader than the power-on rotor speed limits because of the required autorotational rotor speed characteristics. Thus, the auxiliary rotor design conditions concern the maximum and minimum design rotor speeds in conjunction with the maximum positive or negative pitch thrust as appropriate. Thrust capability and precone angle of the rotor, if any, will significantly influence the rotor design loads. The variations in rotor design features and an example of substantiation would be too lengthy to include here. However, ANC-9, "Aircraft Propeller Handbook," contains principles that may be applied to tail rotor designs. Tail rotors may be considered a special propeller design.

(iv) Bearings are generally used in the tail rotor installation to allow flapping and feathering motion of the blades. The bearings manufacturer's ratings of these bearings must not be exceeded. Bearings generally used in main and tail rotors are classified as ABEC Class 3, 5, or 7. Class 7 is the highest quality presently available. Satisfactory completion of the endurance tests of §§ 29.923 and 29.927 is a means of proving that use of a particular bearing is satisfactory.

(v) The analysis must include appropriate special factors, casting factors, bearing factors, and fitting factors prescribed by §§ 29.619, 29.621, 29.623, and 29.625, respectively. The fitting factor of 1.15 must be applied in the analysis of the tail rotor installation.

AC 29.401A. <u>§ 29.401 (Amendment 29-31) AUXILIARY ROTOR ASSEMBLIES</u>.

a. <u>Explanation</u>. Amendment 29-31 removed this section since the requirements are adequately addressed in §§ 29.337, 29.339, and 29.341.

b. <u>Procedures</u>. The policy material pertaining to this section is retained as supplemental information.

AC 29.403. <u>§ 29.403 AUXILIARY ROTOR ATTACHMENT STRUCTURE</u>.

a. <u>Explanation</u>.

(1) The auxiliary rotor attachment structure(s), which is considered to include gear boxes, must be designed to withstand design limit loads that occur in flight and on landing. These design loads that generally consist of the following must be established for the particular flight and landing condition under consideration.

(i) Inertia loads generated by linear and angular accelerations of the auxiliary rotors and their gear boxes, combined with

(ii) Thrust and torque loads developed by the auxiliary rotors.

The linear and angular acceleration loads imposed by the weight of the tail rotor and gearbox are generally derived from airframe loads data. Thrust and torque output of the tail rotor are derived during external aerodynamic and landing loads development for pertinent flight and landing conditions.

(2) General rules related to proof of structure loads and factor of safety are §§ 29.307, 29.301, 29.303, and 29.305.

b. <u>Procedures</u>.

(1) The angular and linear acceleration loads combined with appropriate tail rotor thrust and torque for the critical conditions shall be imposed on the tail rotor gearbox mount lugs, the airframe mounting structure, and the attaching hardware.

(2) The yaw and maximum power climb conditions are generally critical. Landing and maneuvering conditions with and without power may also impose high inertia and rotor thrust and torque loads on the attachment structure.

(3) The derivation of the loads and conditions are too extensive to include here. Additional information can be found in the U.S. Army Material Command Report AMCP 706-201, “Engineering Design Handbook: Helicopter Engineering, Part One, Preliminary Design.”

AC 29.403A. <u>§ 29.403 (Amendment 29-31) AUXILIARY ROTOR ATTACHMENT STRUCTURE</u>.

a. <u>Explanation</u>. Amendment 29-31 removed this section since the requirements are adequately addressed in §§ 29.337, 29.339, and 29.341.

b. <u>Procedures</u>. The policy material pertaining to this section is retained as supplemental information.

AC 29.411. § 29.411 GROUND CLEARANCE: TAIL ROTOR GUARD.

a. Explanation.

(1) The rule requires specific protection to prevent the tail rotor from contacting the landing surface during a normal landing if it is possible that the tail rotor will contact the surface. The rule states that it must be impossible for the tail rotor to contact the surface during a normal landing.

(2) If a guard is required, the guard and its supporting structure must withstand suitable design loads.

(3) Section 29.501(c)(1) contains skid landing gear drag requirements that may be applied to the guard design loads.

b. Procedures.

(1) The applicant may submit sketches or drawings showing probable clearance with typical level landing surfaces during normal landings. Typical attitudes such as nose high autorotation, or autorotation with power-on landing, or other possible tail low attitudes should be investigated. If the drawings or sketches reveal that it is not likely the tail rotor will contact the landing surface, this minimum clearance with the landing surface may be confirmed during official FAA/AUTHORITY flight tests, such as HV and landing tests. The clearance may be confirmed by having a frangible device of suitable length (i.e., a balsa wood dowel) extending beyond the guard and attached to the tail rotor guard or other appropriate fuselage part. If the device is not damaged, broken, or no contact is made with the surface, compliance has been demonstrated.

(2) If it is possible for the tail rotor guard to contact the landing surface suitable design loads must be established for the guard. ANC-2a dated March 1948, “ANC Bulletin Ground Loads,” paragraph 6.4, entitled “Tail Bumper Criteria,” is an acceptable means of deriving the rotorcraft kinetic energy that shall be absorbed by the guard. This method is noted here for convenience.

(i) The tail rotor guard shall be able to absorb the kinetic energy of the rotorcraft in its most unfavorable CG position in the tail down landing attitude. The kinetic energy that the tail rotor guard shall be capable of absorbing must be determined as follows:

$$KE = \frac{WV_S^2}{2g} \times \frac{K_Y^2}{(K_Y^2 + 1_B^2)}$$

where-- V_S = vertical speed ft/sec, derived from § 29.725(a)
K_Y = pitching radius of gyration - ft. from pitching axis
1_B = distance from most critical CG location to the guard or bumper contact point - ft.
W = gross weight less rotor lift from § 29.473(a) - lbs.
G = 32.2 ft./sec^2

(ii) Other, more recent, analytical techniques (most utilizing computer programs) may, of course, be used rather than the ANC-2a means after proper substantiation for applicability and validity.

(iii) The tail rotor guard shall not fail when the limit and ultimate load, which is derived from a combination of the limit kinetic energy and the guard resulting limit deflection required to dissipate the energy, is imposed on the guard and the rotorcraft tail (see § 29.305).

(3) Substantiation of the guard, skid, or bumper for the design loads derived may be accomplished by test or analysis as stated in § 29.307(a).

(4) Several rotorcraft tail rotor guards are installed solely for the protection of ground personnel from the rotating tail rotor. For guards installed for this purpose, the applicant should use prudent and reasonable design loads and features. Such guards should not present a hazard to the rotorcraft because of its design features.

AC 29.413. § 29.413 STABILIZING AND CONTROL SURFACES.

a. Explanation. Minimum design loads are specified for stabilizing as well as control surfaces.

(1) Paragraph (a) of the rule requires application of minimum empirical design loads, application of critical maneuvering loads, and application of critical maneuvering loads combined with vertical or horizontal gust loads (30 feet per second per § 29.341).

(2) Paragraph (b) requires load distributions that closely simulate actual pressure distributions. Both spanwise and chordwise distributions are intended.

(3) These surfaces are used for stability and control thereby hopefully extending the CG range and increasing the airspeed of modern designs.

(4) To “closely simulate actual pressure condition” on the surfaces, unsymmetrical loads are also required on horizontal surfaces. An arbitrary distribution, if conservative, may be used.

(5) It is noted § 29.571 requires fatigue substantiation of the flight structure which will include control and stabilizing surfaces.

(6) If the surface is controllable, a proof and operation test of the surface control system is required by §§ 29.681 and 29.683.

b. Procedures. Modern rotorcraft designs have generally employed a fixed or a wholly movable, not split or divided, stabilizing or control surface.

(1) Design Loads.

(i) Limit loads of 15 pounds per square foot will apply up to approximately 90-knot design airspeed. Above a 90-knot design airspeed (V_D), the coefficient (C_N = 0.55) imposes higher limit loads on the surface.

(ii) In addition, combined maneuvering and gust loads may impose the highest limit loads on the control surfaces of rotorcraft. This is attributed to the increase in speed (horizontal gust) and to the change in angle of attack and change in airspeed (vertical gust). Imposing the horizontal gust (30 feet per second or 17.8 knots) on the surface in combination with 130-knot design speed results in a 30 percent increase in the design load. The gust conditions cause a significant increase in design loads due to a change in angle of attack, with a change in resultant airspeed, or due to the increase in airspeed.

(iii) The applicant may choose to derive the limit loads using maximum aerodynamic coefficients for the surface under consideration at the maximum design airspeed combined with a 17.8-knot gust. This would be acceptable provided these design loads exceed the minimum loads derived from a C_N = 0.55 at design airspeed or exceed 15 pounds per square foot load on the surface.

(2) The load distribution on the surface should closely simulate actual pressure distributions.

(i) The spanwise load may be rectangular or other acceptable conservative distributions may be used. The method developed by O. Schrenk in NACA TM 948, 1940, is an acceptable method for approximation of spanwise distribution.

NOTE: The method is valid for aspect ratios of 5 to 12 and for rectangular planforms such as used on rotorcraft, other planforms may be acceptable as prescribed in the TM.

(ii) The chordwise distribution appropriate for the aerodynamic shape should be used.

(iii) The flight load survey conducted under § 29.571 may be used to confirm design parameters and possible load distribution data. On controllable surfaces, the pitching moment (control loads) is measured for fatigue substantiation of the control system. The control stabilizing surfaces are subject to loads measurement and possible fatigue tests for fatigue substantiation also.

(3) Proof of the structure for the required loads is specified in §§ 29.301, 29.303, 29.305, and 29.307. Tests or analysis may be used as prescribed. If analysis is used, fitting factors and other appropriate factors prescribed by the rules of §§ 29.625, 29.621, and 29.623 will be required in the analysis.

AC 29.413A. <u>§ 29.413 (Amendment 29-31) STABILIZING AND CONTROL SURFACES</u>.

a. <u>Explanation</u>. Amendment 29-31 removed this section since the requirements are adequately addressed in §§ 29.337, 29.339, and 29.341.

b. <u>Procedures</u>. The policy material pertaining to this section is retained as supplemental information especially as reference material for paragraph AC 29.341 (§ 29.341).

AC 29.427. <u>§ 29.427 (Amendment 29-31) UNSYMMETRICAL LOADS</u>.

a. <u>Explanation</u>. Amendment 29-30 added the standard and Amendment 29-31 amended it. Minimum unsymmetrical design loads are specified for horizontal tail surfaces and also vertical tail surfaces whenever they support the horizontal tail surfaces.

(1) Loads are derived by rational analysis, or for earlier certification bases, the prescribed empirical loads of § 29.413 may be used. Section 29.413 was removed by Amendment 29-31 since the requirements are adequately addressed in §§ 29.337, 29.339, and 29.341.

(2) Rational loads, appropriate for the aerodynamic surfaces, should be distributed according to the standard.

(3) When vertical tail surfaces support the horizontal tail surfaces, the vertical tail surfaces and supporting surfaces are required to support the critical combination of vertical and horizontal surface loads distributed as shown.

b. <u>Procedures</u>. Two basic loading conditions are required by § 29.427 for each of the two basic empennage configurations shown.

(1) Horizontal surfaces supported by the tail boom or fuselage. Structural substantiation should be provided for all six combinations shown in figure AC 29.427-1. All of these empirical loading distributions should be used unless rational analysis shows one or more of each set of conditions to be non-critical or equal or more realistic distributions are substantiated. Rectangular spanwise air load distribution should be used unless more rational distribution is substantiated. If end plates are used, the air loads should be distributed accordingly.

(i) First unsymmetrical loading condition:

(A) 100 percent of the flight load is applied to one side of the plane of symmetry; and 0 percent of the flight load is applied on the other side of the plane of symmetry.

(B) For surfaces with end plates or other similar devices, the load distribution will be changed accordingly.

(ii) Second unsymmetrical loading condition:

50 percent of the flight load on one side of the plane of symmetry acting up; and
50 percent of the flight load on the other side of the plane of symmetry acting down.

(2) Horizontal surfaces supported by a vertical surface. Structural substantiation should be provided for all six combinations shown in figure AC 29.427-2. All of these empirical loading distributions should be used unless rational analysis shows one or more of each set of conditions to be non-critical or equal or more realistic distributions are substantiated. Rectangular spanwise air load distribution should be used unless more rational distribution is substantiated. If end plates are used, the air loads should be distributed accordingly.

(i) First unsymmetrical loading condition:

100 percent of the flight load on one side of the plane of symmetry; and 0 percent of the flight load on the other side of the plane of symmetry.

(ii) Second unsymmetrical loading condition:

50 percent of the flight load on one side of the plane of symmetry acting up; and
50 percent of the flight load on the other side of the plane of symmetry acting down.

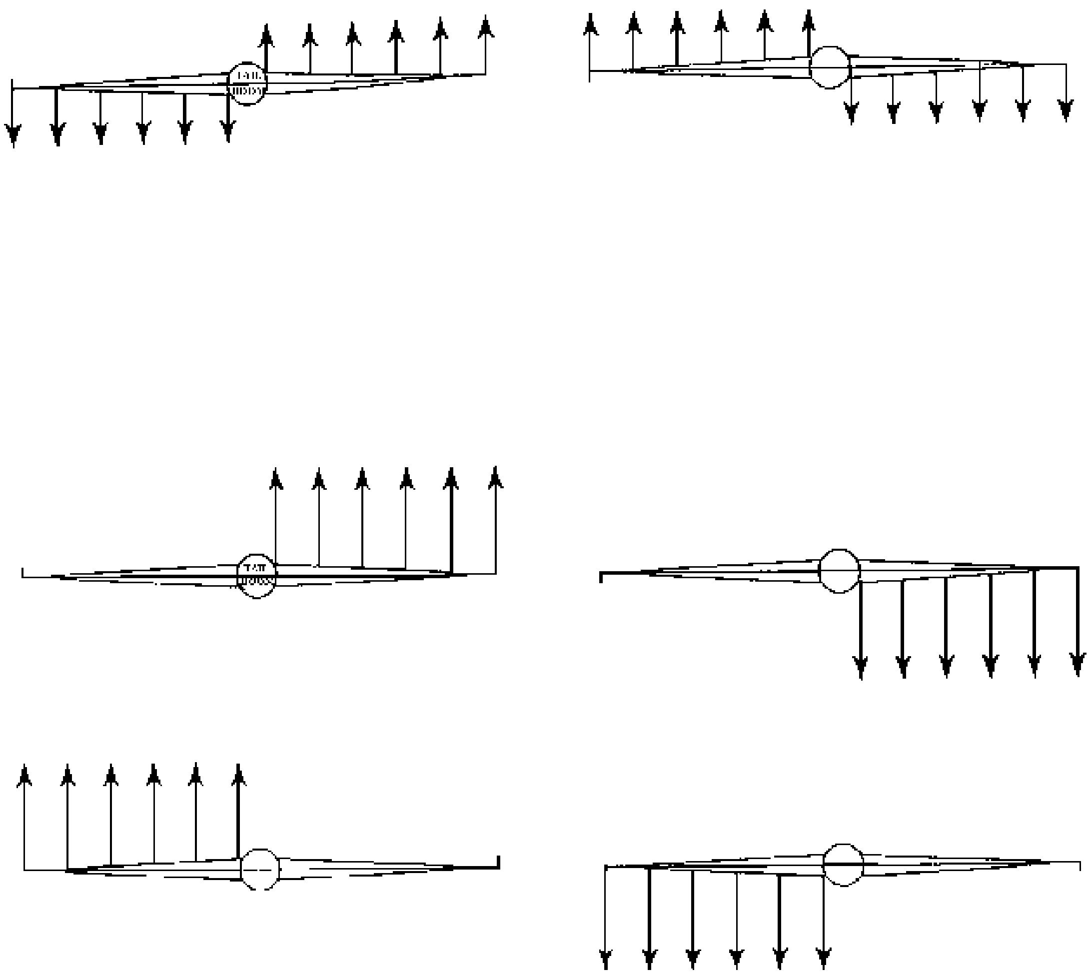


Figure AC 29.427-1 (View Looking Forward)

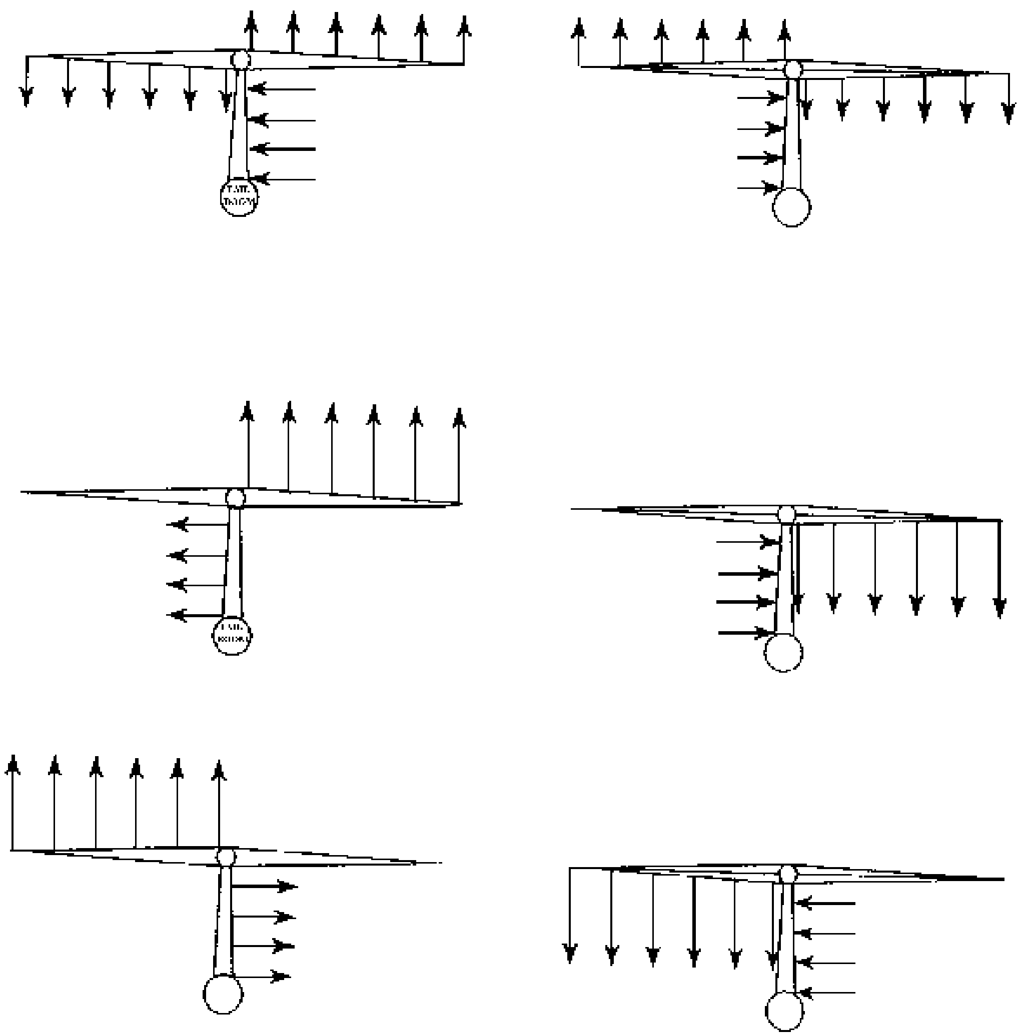


Figure AC 29.427-2 (View Looking Forward)

SUBPART C - STRENGTH REQUIREMENTS

GROUND LOADS

AC 29.471. § 29.471 GROUND LOADS - GENERAL.

a. Explanation. This regulation specifies that limit ground loads must be considered which are:

(1) External loads caused by landing (ground) conditions and by ground taxiing loads as specified in § 29.235.

(2) Loads considering the rotorcraft structure as a rigid body.

(3) Loads in equilibrium with linear and angular inertia loads.

(4) The critical center of gravity "must be selected so that the maximum design loads are obtained in each landing gear element."

b. Procedures.

(1) The standards to be considered are specified in §§ 29.473 through 29.511. These associated standards cover landing gear arrangements, landing conditions, and ground handling conditions.

(2) Drop tests are required for determination of landing load factors. See paragraph AC 29.723.

(3) The application of the design loads derived from the landing load factors will be as specified for each element affected by landing or ground handling loads.

(4) During the applicant's flight test program, the ground, landing, and taxiing load factors may be monitored to assure the design load factors used are adequate. See paragraph AC 29.235 for § 29.235 guidance.

AC 29.473. § 29.473 (Amendment 29-3) GROUND LOADING CONDITIONS AND ASSUMPTIONS.

a. Explanation. The rotorcraft is to be designed for the maximum weight. A rotor lift of two-thirds of the design maximum weight may be used. The minimum limit landing load factor is determined by the drop tests of § 29.725. Provisions are made for supplementary energy absorption devices that have triggering mechanisms.

b. Procedures. Loads for the landing conditions are derived considering mass (equal to the maximum weight) and rotor lift (equal to two-thirds of the maximum weight) acting through the center of gravity throughout the landing impact. Unbalanced external loads resulting from asymmetric loading conditions are reacted as specified in the individual subparagraphs.

NOTE: If supplementary energy absorption devices are used, neither they nor their triggering devices may fail under the loads established by the limit drop tests or the reserve energy absorption drop tests.

AC 29.475. § 29.475 TIRES AND SHOCK ABSORBERS.

a. Explanation. This section specifies the tire and shock absorber position to be used in ground load derivations.

b. Procedures. Ground loads are to be derived with the tires in static (1g) position and the shock absorbers "in their most critical position." The determination of the "most critical position" for the shock absorbers generally requires a load versus deflection test or analysis of the shock absorber system and a determination of the effect of both load and deflections on the shock absorber, attachment structure, and substructure designed by ground loads.

AC 29.477. § 29.477 LANDING GEAR ARRANGEMENT.

a. Explanation. This section specifies the individual standards to be used for ground load conditions for rotorcraft having two wheels aft and one or more wheels forward of the center of gravity.

NOTE: § 29.497 gives ground loading conditions for landing gear with tail wheels, and § 29.501 gives ground loading conditions for landing gear with skids.

b. Procedures. The ground loading conditions of §§ 29.235, 29.479 through 29.485, and 29.493 will be used for rotorcraft having two wheels aft and one or more wheels forward of the center of gravity. This includes forward wheels on separate axles.

AC 29.479. § 29.479 LEVEL LANDING CONDITIONS.

a. Explanation. This section provides explicit level landing load criteria for landing gear with two wheels aft and one or more wheels forward of the center of gravity.

(1) Level landings--

(i) Each wheel contacting the ground simultaneously; and

(ii) Aft wheels contacting the ground with forward wheels just clear of the ground.

(2) Application of loads--

(i) Maximum design vertical loads applied alone;

(ii) The maximum design vertical loads applied with a drag load of at least 25 percent of the vertical load (applied at the ground contact area); and

(iii) The vertical load at the instant of peak drag load in conjunction with the peak drag load. A ground speed and load application is specified.

(3) A 40 percent/60 percent load distribution between wheels for configurations having two forward wheels including quadricycle. This distribution between wheels on a common axis is to be applied for the conditions of vertical loads only, and for vertical loads combined with drag loads of 25 percent of the vertical loads. Section 29.511 concerns a 60 percent to 40 percent ground load distribution between multiple-wheel units. See paragraph AC 29.511 for dual wheels on a common axle or axis.

(4) Aircraft pitching moments are to be reacted by the forward landing gear or by the angular inertia forces when the forward landing gear is clear of the ground as specified.

b. Procedures.

(1) The specified loading conditions will be used in load derivations.

(2) The critical center of gravity condition will be used for each gear and gear support structure.

(i) The aft center of gravity condition with the forward gear clear will normally be critical for the aft gear and gear supports.

(ii) The forward center of gravity condition with each gear contacting the ground simultaneously will normally design forward gear elements critical for vertical loads.

(iii) The forward center of gravity condition with the forward gear clear may result in high load factors, angular plus linear, that will greatly affect security of items of significant mass.

(3) The vertical load, at the instant of peak drag load combined with the peak drag component, can be determined from drop tests utilizing wheel spin-up or it can be analytically determined. If analysis is used, it must successfully correlate with the results of a previous well-instrumented test program.

AC 29.481. <u>§ 29.481 TAIL-DOWN LANDING CONDITIONS</u>.

a. <u>Explanation</u>. This section provides the criteria for tail-down landing conditions, i.e., "the maximum nose-up attitude allowing ground clearance" with ground loads acting "perpendicular to the ground."

b. <u>Procedures</u>.

(1) The tail-down landing condition will be used to check (by analysis or test) for criticality of landing gear or support structure. This attitude generally creates the highest forward loads on the landing gear in combination with vertical loads.

(2) The tail-down landing condition may be the critical condition for both landing load factor and for energy absorption by the main gear. Section 29.725 requires that "each landing gear must be tested in the attitude simulating the landing condition that is most critical." Where questions exist as to the critical attitude, both level landing and tail-down landing attitudes should be used in drop tests required by § 29.725.

AC 29.483. <u>§ 29.483 ONE-WHEEL LANDING CONDITIONS</u>.

a. <u>Explanation</u>. This section gives the condition to be used for one-wheel landing conditions. Only the vertical load condition of § 29.479(b)(1) is required.

b. <u>Procedures</u>. The one-wheel landing condition is generally critical for the landing gear-to-fuselage attachments and the landing gear elements between the attachments. Unbalanced external loads are reacted by rotorcraft inertia. Large items of mass located radially from the center of gravity (aircraft centerline may be used) should also be structurally substantiated for the combined rolling (angular) and linear accelerations of this loading condition.

AC 29.485. <u>§ 29.485 LATERAL DRIFT LANDING CONDITIONS</u>.

a. <u>Explanation</u>.

(1) This section provides the loading conditions which impose side (and vertical) loads on the landing gear. A level landing attitude is specified. Two main conditions required are--

(i) Only the aft wheels in contact with the ground; and

(ii) All wheels contacting the ground simultaneously.

(2) Loads. The vertical loads to be applied with the side loads are specified as "one-half of the maximum ground reactions of § 29.479(b)(1)." These vertical loads are the level landing loads considering both contact and noncontact with the ground by the forward wheels.

(i) One side load condition is specified as “0.8 times the vertical reaction acting inward on one side and 0.6 times the vertical reaction acting outward on the other side” when only the aft wheels contact the ground.

(ii) The other side load condition (for all wheels contacting the ground) specifies the 80 percent inward/60 percent outward distribution for the aft wheels and 0.8 times (80 percent) the vertical reaction for the forward wheels.

b. Procedures. The loading conditions, as specified, are applied to the landing gear and attaching structure. The loads are applied at the ground contact point, except for full swiveling gear which has the load applied at the center of the axle. In other words, full swiveling gear is considered to have swiveled to a static position under the side load before the design vertical and side loads are achieved. The landing gear backup structure, as well as the landing gear itself, will be substantiated for these side load conditions.

AC 29.493. § 29.493 BRAKED ROLL CONDITIONS.

a. Explanation. This section provides two loading conditions for ground braking operations. Specific vertical loads in conjunction with drag loads (due to braking) are to be considered. The limit vertical load factor is 1.33 for condition of all wheels in contact with the ground, and 1.0 for condition of aft wheels only in contact with the ground and nose wheel clear. The drag load on wheels with brakes is 0.8 times the vertical load or the drag load value based on limiting brake torque, whichever is less.

b. Procedures. The braking loads are calculated from the specified criteria with the shock absorbers in their static (normal) positions and with the drag loads applied at the ground contact point. Structural substantiation of the affected structure may be accomplished by test or analysis. If tests are used, the wheel and tire assembly is commonly replaced with a test fixture so the limit loads and static deflections specified can be more accurately controlled. The test specimen should be complete enough to assure that the landing gear structure and the attach and backup structure are adequately substantiated.

AC 29.497. § 29.497 GROUND LOADING CONDITIONS: LANDING GEAR WITH TAIL WHEELS.

a. Explanation. This section provides the loading conditions for landing gear designs with tail wheels.

(1) Level landings are to consider the following:

(i) All wheels (main and tail) contacting the ground simultaneously, as well as only forward main wheels contacting the ground.

(ii) Maximum design vertical loads applied alone.

(iii) The maximum design vertical loads combined with a drag load of at least 25 percent of the vertical loads for both conditions.

(2) Nose-up landings with only the rear wheel or wheels initially contacting the ground must be considered unless shown to be extremely remote.

(3) Level landings on one forward wheel only are to be considered. Drag loads are not required.

(4) Side load conditions are imposed on the main wheels and tail wheels for level landing attitudes. Criteria for full swiveling and locked tail wheels are included in this standard.

(5) Braked roll conditions are specified for the level landing attitudes.

(6) Rear wheel turning loads are also specified for swiveling and locked tail wheels.

(7) Taxiway condition loads for the landing gear and rotorcraft are those that "occur when the rotorcraft is taxied over the roughest ground that may reasonably be expected in normal operation." The aircraft design load factors should not be exceeded during the evaluation. Section 29.235 contains an identical standard that applies to all types of wheel landing gear.

b. Procedures.

(1) The specified loading conditions are to be used in load derivations.

(2) The critical center of gravity condition is used for each gear and gear support structure.

(i) The forward center of gravity condition with the tail gear clear will normally be critical for the forward gear and gear supports.

(ii) The aft center of gravity condition with the tail gear clear should be checked for criticality of security of large mass items located forward of the center of gravity. Vertical and angular accelerations are additive under this landing condition.

(iii) The aft center of gravity condition with each gear contacting the ground simultaneously will generally design tail gear elements critical for vertical loads. The other conditions are generally less severe but must be proven.

(3) For nose-up landing procedures use § 29.481. The reference to "extremely remote" in § 29.497(d)(2) predates current §§ 25.1309, 29.1309, and AC 25.1309.1.

This phrase has been used to require consideration of nose-up landings unless features of design are present which prevent nose-up landings or where such landings are unlikely during the life of the rotorcraft. See paragraph AC 29.481.

(4) Use § 29.483 for one-wheel landing procedures, paragraph AC 29.483.

(5) Use § 29.485 procedures for side load conditions, paragraph AC 29.485.

(6) Use § 29.493 procedures for braked roll conditions, paragraph AC 29.493.

(7) For rear wheel turning loads, swiveling of tail landing gears is allowed as in basic side load conditions. The side load is applied at the axle, or if the wheel is locked, the load is applied at ground contact. Rear wheels are loaded with the critical vertical static load in conjunction with an equal side load to substantiate the tail gear.

(8) Since the rotorcraft is to be designed for load factors that will not be exceeded during taxi tests or other conditions, an instrumented taxi test program will be necessary. Use § 29.235, paragraph AC 29.235.

AC 29.501. § 29.501 (Amendment 29-3) GROUND LOADING CONDITIONS: LANDING GEAR WITH SKIDS.

a. Explanation. This section provides the ground loading conditions for landing gear with skids. The loading conditions are similar to those for wheeled gear except for the following criteria which are unique to skid gears:

(1) Structural yielding (plastic deformation) of elastic spring members under limit loads is allowed.

(2) Design ultimate loads for elastic spring members need not exceed the loads obtained in a drop test with a drop height of 1.5 times the limit drop height. The rotorcraft and the landing gear attachments are subject to the prescribed design ultimate loads.

(3) The gear must be in its most critically deflected position (similar to § 29.475).

(4) Ground reactions are rationally distributed along the bottom of the skid unless otherwise specified. Paragraph (f) concerns specific “concentrated” and arbitrary load conditions.

(5) Drag loads are 50 percent of vertical reactions rather than the 25 percent for wheeled gear.

(6) Side loads are 25 percent of the total vertical reaction rather than the 60-80 percent for wheeled gear.

(7) Side loads are applied to one skid only (inward acting and outward acting) with resulting unbalanced moment resisted by angular acceleration.

(8) A ground reaction load of 1.33 times the maximum weight is to be applied at 45° from the horizontal axis:

(i) Distributed among or between the skids;

(ii) Concentrated at the forward end of the straight portion of the skid tube; and

(iii) Applied only to the forward end of the skid tube and its attachment to the rotorcraft.

(9) A concentrated vertical load equal to one-half of the design limit vertical load is to be applied at a point midway between the skid tube attachments.

b. Procedures.

(1) The specified loading conditions are to be used in load derivations.

(2) The critical center of gravity conditions are to be used for each gear and gear support structure. Asymmetry of the skid tubes, cross tubes, and gear attachments are to be considered in determining the critical center of gravity condition.

(3) The rotorcraft and landing gear attachment must be substantiated for ultimate landing loads by either test or analysis utilizing an ultimate load factor of 1.5 in accordance with § 29.303. The elastic spring members may be analyzed or static tested for ultimate loads (and deflections) using either a factor of safety of 1.5 or one associated with an "ultimate" drop height of 1.5 times the limit drop height. Substantiation by "ultimate" drop tests may be used provided all combinations of critical parameters are included in the total substantiation effort. This method will require a series of tests using several test specimens, or a limited number of drop tests plus further substantiations by static tests or analyses for additional critical conditions not covered by the drop test(s).

AC 29.501A. § 29.501 (Amendment 29-30) GROUND LOADING CONDITIONS: LANDING GEAR WITH SKIDS.

a. Explanation. Amendment 29-30 relaxes previous requirements in two cases by:

(1) Allowing the total sideload of § 29.501(d)(3) to be distributed "equally between skids" rather than being "applied along the length of one skid only;" and,

(2) Allowing the concentrated load of § 29.501(f)(2)(ii) to be distributed over 33.3 percent of the skid (between skid tube attachments) rather than being "concentrated at a point midway between the skid tube attachments."

b. Procedures. The previous procedures (through Amendment 29-19) continue to apply to Amendment 29-30 except for the use of the new load distributions.

AC 29.505. § 29.505 SKI LANDING CONDITIONS.

a. Explanation. This is an optional requirement for ski operations. The regulation specifies vertical loads, side loads, and torque loads (M_Z) to be applied to ski installations. The four loading conditions to be applied at the pedestal bearings are:

(1) Simultaneous application of Pn, up load, and Pn/4, horizontal load.

(2) Up load of 1.33 P.

(3) Side load of 0.35 Pn.

(4) Torque load of 1.33 P (in foot-pounds), about vertical axis through the centerline of the pedestal bearings.

NOTE: Where P is the maximum static weight on each ski and n is the limit load factor obtained from drop tests. The load factor obtained from wheel or skid landing gear drop tests may be used.

b. Procedures. Structural substantiation may be accomplished by static test or analysis using the specified loads. Skis generally have a limit load rating. The design loads derived for this standard must not exceed the rating. TSO-c28 concerns, in part, standards for aircraft skis.

AC 29.511. § 29.511 (Amendment 29-3) GROUND LOAD: UNSYMMETRICAL LOADS ON MULTIPLE-WHEEL UNITS.

a. Explanation. Two loading conditions are provided to account for unsymmetrical loads on multiple-wheel units due to landing and normal operations over crowned runways and taxiways and to account for deflated tires. They are:

(1) Sixty percent of total ground reaction applied to one wheel of a dual wheel unit and 40 percent to the other.

(2) Sixty percent of the "specified load for the gear unit" is applied to the wheel with an inflated tire when the other tire is deflated (the 60 percent load may not be less than the 1g static load).

NOTE: The 60:40 distribution also applies to nose wheel units as noted in § 29.479(b)(4).

b. Procedures. Structural substantiation may be accomplished by static test or analysis using the specified load. As provided by the standard, the total load on the gear units may neglect the transverse shift of the load centroid due to unsymmetrical load distribution; i.e., the external load for each gear may be calculated considering the same load centroid as with symmetrical wheel loads, and then the external load for each gear is divided in accordance with the distributions of § 29.511(a) and (b) between the wheels.

SUBPART C - STRENGTH REQUIREMENTS

WATER LOADS

AC 29.519. § 29.519 (Amendment 29-30) HULL TYPE ROTORCRAFT: WATER-BASED, AMPHIBIAN.

a. Explanation.

(1) This regulation provides design criteria for amphibian rotorcraft with hull provisions.

(2) The most severe wave heights for which approval is desired are to be considered. A minimum of sea state 4 condition wave heights should be considered (reference paragraph AC 29.801 for a description of sea state 4 conditions).

(3) A rotor lift of two-thirds of the rotorcraft weight may be applied during landing impact.

(4) Vertical landing conditions are specified as:

(i) Zero forward speed.

(ii) Likely pitch and roll attitudes.

(iii) Vertical descent velocity $\geq$ 6.5 FPS.

(5) Forward speed landing conditions are specified as:

(i) Forward velocities of zero to 30 knots (a 30-knot limit may be reduced if it can be demonstrated that the maximum forward velocity selected would not be exceeded in a normal one-engine-out landing).

(ii) Likely pitch, roll, and yaw attitudes.

(iii) Vertical descent velocity $\geq$ 6.5 FPS.

(6) Auxiliary float immersion conditions are specified to be applied unless it can be shown that full immersion is unlikely. If full immersion is unlikely, the highest float buoyancy load is specified that considers loading of the float immersed to create restoring moments which compensate for upsetting moments caused by side wind, asymmetrical rotorcraft loading, water wave action, and rotorcraft inertia.

b. Procedures.

(1) Tests should be conducted to establish procedures for water entry. These tests should include determination of optimum pitch attitude and forward velocity for landing in a calm sea as well as entry procedures for the highest sea state to be demonstrated (e.g., the recommended part of the wave on which to land and direction of landing relative to crest/trough direction).

(2) The landing structural design consideration should be based on water impact with a rotor lift of not more than two-thirds of the maximum design weight acting through the center of gravity under the following conditions:

(i) Vertical Landing Conditions.

(A) Zero forward velocity.

(B) The optimum pitch attitude as determined in paragraph AC 29.519b(1) with consideration for pitch attitude variations that would reasonably be expected to occur in service.

(C) Vertical descent velocity of 6.5 FPS or greater.

(D) Likely roll attitudes.

(ii) Forward Speed Landing Conditions.

(A) Forward velocities of zero to 30 knots (or a reduced maximum forward velocity if it can be demonstrated that a lower maximum velocity would not be exceeded in a normal one-engine-out landing).

(B) The optimum pitch attitude as determined in paragraph AC 29.519b(1) with consideration for pitch attitude variations that would reasonably be expected to occur in service.

(C) Vertical descent velocity of 6.5 FPS or greater.

(D) Likely roll and yaw attitudes.

(3) Landing load factors may be determined by--

(i) Landing gear drop tests for limited amphibian;

(ii) Water drop tests for amphibian; or

(iii) Analysis based on tests.

(4) Water load distribution should be determined by tests or analysis based on tests.

(5) Auxiliary float loads should be determined by full immersion or restoring moments required to react upsetting moments caused by side wind, asymmetrical rotorcraft loading, water wave action, and rotorcraft inertia. Auxiliary float loads may be determined by analysis. Load distributions should be determined by tests or analysis based on tests.

AC 29.521. § 29.521 (Amendment 29-3) FLOAT LANDING CONDITIONS.

a. Explanation. This is an optional requirement for float operations, and it applies only when float operations are requested. The regulation specifies vertical loads, aft loads, and side loads to be applied to the float installations. The two loading conditions to be applied are:

(1) Up-load Condition.

(i) A vertical load appropriate to a landing load factor determined under § 29.473(b).

(ii) The resultant water reaction passes vertically through the aircraft CG.

(iii) An aft load equal to 25 percent of the vertical load.

(2) Side-load Condition.

(i) A vertical load equal to 75 percent of the vertical load for the up-load condition.

(ii) Vertical load equally divided among the floats.

(iii) A side load at each float equal to 25 percent of the vertical load at each float.

b. Procedures.

(1) The vertical load factor is determined by drop tests in accordance with §§ 29.473(b) and 29.725. The floats may be drop tested, or they may be assumed to have the same load factor as wheeled gear which have been drop tested.

(2) Structural substantiation may be accomplished by either static tests or analysis using the specified loads. The load distribution on the floats may be realistically based on hydrostatic pressure distributions or conservative pressure distributions.

SUBPART C - STRENGTH REQUIREMENTS

MAIN COMPONENT REQUIREMENTS

AC 29.547. § 29.547 (Amendment 29-4) MAIN ROTOR STRUCTURE.

a. Explanation. This regulation requires the main rotor structure to be designed to the static load requirements of §§ 29.337 through 29.351 (vertical maneuvering loads, vertical and horizontal gust loads, and yawing maneuver loads). In addition, the main rotor blades, hubs, and flapping hinges are specified to be designed for impact forces of each blade against its stop during ground operation and for specified limit torque at any rotational speed including zero. The torque forces (from the drive system) are distributed to the rotor blades as specified.

b. Procedures.

(1) Substantiation in compliance with this standard is accomplished by application of the flight loads of §§ 29.337 through 29.351 and the torque loads of § 29.361 to the rotor structure by stress analyses and/or static tests. The use of wind tunnel data as well as flight loads survey data may be used to generate and/or check the external load magnitudes and distributions.

(2) Where new materials are used in the main rotor structure, such as composites containing plastics, the effects of temperature and humidity are to be considered in accordance with § 29.603, and the effects of uncertainties in manufacturing processes or inspection methods are to be considered in accordance with § 29.619.

(3) The design impact forces of each blade must be imposed against the blade stop or stops. Impact loads from 2 to 3 g's have been commonly used to provide rotor structure protection against blades impacting against lower (droop) stops. Different values may be used for flapping and lag stops as determined by a rational basis. Appropriate monitoring of the blades, hubs, flapping hinges, and stops during laboratory tests, ground endurance tests, and flight tests should ensure that the stops are sufficient for ground operation loads (taxiing, backing, etc.), training, and offshore platform landings. Taxiing should consider typical obstacles such as pavement edges, ropes, air lines, and so forth. The design torque loads are derived as prescribed.

AC 29.547A. § 29.547 (Amendment 29-40) MAIN ROTOR AND TAIL ROTOR STRUCTURE.

a. Explanation. Amendment 29-40 revised § 29.547 to add requirements to perform a design assessment. FAR 29.547 (a) and (b) set forth a definition of a rotor and its associated components and requires a design assessment to be performed. The intent of these paragraphs is to identify the critical components and/or clarify their design integrity to show that the basic airworthiness requirements which are applicable to the rotors will be met.

A design assessment of the rotors should be carried out in order to substantiate that they are of a safe design and that compensating provisions are made available to prevent failures classified as hazardous and catastrophic in the sense specified in paragraph b below. In carrying out the design assessment, the results of the certification ground and flight testing (including any failures or degradation) should be taken into consideration. Previous service experience with similar designs should also be taken into account (see also FAR 29.601(a)).

b. Definitions. For the purposes of this assessment, failure conditions may be classified according to the severity of their effects as follows:

(1) Minor. Failure conditions which would not significantly reduce rotorcraft safety, and which involve crew actions that are well within the crew capabilities. Minor failure conditions may include, for example, a slight reduction in safety margins or functional capabilities, a slight increase in crew workload, such as routine flight plan changes, or some inconvenience to occupants.

(2) Major. Failure conditions which would reduce the capability of the rotorcraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example, a significant reduction in safety margins or functional capabilities, a significant increase in crew work load or in conditions impairing crew efficiency, or discomfort to occupants, possibly including injuries.

(3) Hazardous. Failure conditions which would reduce the capability of the rotorcraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be --

(i) A large reduction in safety margins or functional capabilities.

(ii) Physical distress or higher workload such that the flight crew cannot be relied upon to perform their tasks accurately or completely.

(iii) Serious or fatal injury to a relatively small number of the occupants.

(iv) Loss of ability to continue safe flight to a suitable landing site.

(4) Catastrophic. Failure conditions which would prevent a safe landing.

(5) Minimize. Reduce to the least possible amount by means that can be shown to be both technically feasible and economically justifiable.

(6) Health Monitoring. Equipment, techniques and/or procedures by which selected incipient failure or degradation can be determined.

c. Procedures.

(1) Failure Analysis. The first stage of the design assessment should be the failure analysis, by which all the hazardous and catastrophic failure modes are identified. The failure analysis may consist of a structured, inductive bottom-up analysis, which is used to evaluate the effects of failures on the system and on the aircraft for each possible item or component failure. When properly formatted, it will aid in identifying latent failures and the possible causes of each failure mode. The failure analysis should take into consideration all reasonably conceivable failure modes in accordance with the following:

(i) Each item/component function(s).

(ii) Item/component failure modes and their causes.

(iii) The most critical operational phase/mode associated with the failure mode.

(iv) The effects of the failure mode on the item/component under analysis, the secondary effects on the rotors and on the rotor drive system, on other systems and on the rotorcraft. Combined effects of failures should be analyzed where a primary failure is likely to result in a secondary failure.

(v) The safety device or health monitoring means by which occurring or incipient failure modes are detected, or their effects mitigated. The analysis should consider the safety system failure.

(vi) The compensating provision(s) made available to circumvent or mitigate the effects of the failure mode (see also paragraph (2) below)

(vii) The failure condition severity classification according to the definitions given in (b) above.

When deemed necessary for particular system failures of interest, the above analysis may be supplemented by a structured, deductive top-down analysis, which is used to determine which failure modes contribute to the system failure of interest.

Dormant failure modes should be analyzed in conjunction with at least one other failure mode for the specific component or an interfacing component. This latter failure mode should be selected to represent a failure combination with potential worst case consequences.

When significant doubt exists as to the effects of a failure, these effects may be required to be verified by tests.

(2) Evaluation of Hazardous and Catastrophic Failures: The second stage of the design assessment is to summarize the hazardous and catastrophic failures and appropriately substantiate the compensating provisions which are made available to minimize the likelihood of their occurrence. Those failure conditions that are more severe should have a lower likelihood of occurrence associated with them than those that are less severe. The applicant should obtain early concurrence of the cognizant certificating authority with the compensating provisions for each hazardous or catastrophic failure.

Compensating provisions may be selected from one or more of those listed below, but not necessarily limited to this list.

(i) Design features; i.e., safety factors, part derating criteria, redundancies, etc.

(ii) A high level of integrity.

(iii) Fatigue tolerance evaluation.

(iv) Flight limitations.

(v) Emergency procedures.

(vi) An inspection or check that would detect the failure mode or evidence of conditions that could cause the failure mode.

(vii) A preventive maintenance action to minimize the likelihood of occurrence of the failure mode including replacement actions and verification of serviceability of items which may be subject to a dormant failure mode.

(viii) Special assembly procedures or functional tests for the avoidance of assembly errors which could be safety critical.

(ix) Safety devices or health monitoring means beyond those identified in (vi) and (vii) above.

AC 29.549. § 29.549 (Amendment 29-26) FUSELAGE AND ROTOR PYLON.

a. Explanation. This regulation requires that the fuselage and rotor pylon (including the tail fin, if any) be designed to withstand the flight loads of §§ 29.337 through 29.351, the ground loads of §§ 29.235, 29.471 through 29.497, skid loads of § 29.501, ski loads of § 29.505, water loads of § 29.521, and rotor loads of § 29.547(d) and (e). The ski and water loads pertain to optional features.

(1) Consideration is also required of --

(i) Auxiliary rotor thrust;

(ii) The torque reaction of each rotor drive system; and

(iii) Balancing air and inertia loads.

(2) Each engine mount and adjacent fuselage must be substantiated as prescribed. In addition, if 2 ½-minute power is used, "each engine mount and adjacent structure must be designed to withstand the loads resulting from a limit torque equal to 1.25 times the mean torque for 2 ½-minute power combined with 1g flight loads." Amendment 29-26 extended paragraph (e) of the standard to 2 ½-minute "OEI power."

b. Procedures. Compliance with this standard is accomplished by application of the specified aircraft loads including engine torque to the fuselage and rotor pylon structure by stress analyses and/or static tests. Drive system torque factors to be used are noted in § 29.547 for the main rotor structure as well as in § 29.549(e).

AC 29.551. § 29.551 AUXILIARY LIFTING SURFACES.

a. Explanation. This regulation specifies that auxiliary lifting surfaces be designed to withstand critical flight and ground loads derived for conditions specified and any "other critical condition expected in normal operation." Stub wings would comply with this standard.

b. Procedures. The surface design loads are derived from the conditions specified. Conservative aerodynamic data, including load distributions, may be used in place of data derived from wind tunnel or instrumented flight testing of the exact aerodynamic shapes involved. Special attention should be placed on concentrated load effects from fuel tanks or other large mass items that may be located in lifting surfaces. These types of load concentrations are to be considered in conjunction with inertia and aerodynamic loads.

SUBPART C - STRENGTH REQUIREMENTS

EMERGENCY LANDING CONDITIONS

AC 29.561 § 29.561 EMERGENCY LANDING CONDITIONS - GENERAL.

a. Explanation.

(1) Occupant protection. The occupants should be protected as prescribed from serious injury during an emergency/minor crash landing on water or land for the conditions prescribed in the standard. The standard states that each occupant should be given every reasonable chance of escaping serious injury in a minor crash landing. In addition, the occupants must be protected from items of mass inside the cabin as well as outside the cabin. For example, a cabin fire extinguisher must be restrained for the load factors prescribed in this section. A transmission or engine must be restrained to the load factors in § 29.561(b)(3) if located adjacent to, above, or behind the occupants.

(2) Load factor determination. Section 29.561(b)(3) specifies certain ultimate inertial load factors but allows a lesser downward vertical load factor by virtue of a 5 FPS ultimate rate of descent at maximum design weight.

(3) Retractable landing gear. For rotorcraft equipped with retractable landing gear only the retracted configuration must be considered.

(4) Fuel tank protection.

(i) Underfloor fuel tanks are specifically addressed in § 29.561(d). The fuselage structure must be designed to resist crash impact loads prescribed in § 29.561(b)(3) and to also protect the fuel tank from rupture as prescribed. The landing gear must be retracted if the rotorcraft is equipped with retractable gears.

(ii) Section 29.963(b), a general rule tank design standard, also refers to § 29.561. This standard specifies that each tank and its installation must be designed or protected to retain fuel without leakage under the emergency landing conditions in § 29.561. Paragraph AC 29.963 relates to this standard.

(5) Door and exit protection. The minor crash conditions contained in § 29.561(b)(3) should also be considered in designing doors and exits (§ 29.783(d) and (g), and § 29.809(e)).

(6) External load considerations. The load factors of § 29.561 and the criteria of § 29.562 are not directly applicable to external load systems. This is because in emergency crash scenarios that involve external loads, the external load is neither typically subjected to the same minor crash loads (§ 29.561) as is the rotorcraft hull and its internal occupants nor are all of the occupant protection criteria (§ 29.562) needed or

practicable to apply. Appropriate safety for external load carriage systems is provided by the criteria of § 29.865. Safety standards for external load attaching means are provided in § 29.865.

b. Procedures.

(1) The design criteria report or another similar report of the rotorcraft structural limits should contain the (ultimate) minor crash condition load factors.

(2) Section 29.785 (paragraph AC 29.875) concerns application of this design standard to seats (berths, litters), belts, and harnesses.

(3) The ultimate design landing and maneuvering load factors may exceed the minor crash condition load factors. The highest load factor derived must be used.

(i) For example, for light weight conditions, the ultimate maneuvering load factor may be 5.25g as specified in § 29.337.

(ii) The ultimate vertical landing load factors derived from §§ 29.471 through 29.521, whichever are appropriate for the design, may exceed the 4.0g down load factor in this section. The rotorcraft landing case design limit contact velocity must be at least 6.5 FPS (see §§ 29.473 and 29.725).

(4) As specified in § 29.561(b)(3)(iv), the downward load factor is 4.0, or a lower design load factor may be used at maximum design weight.

(i) The lower load factor relates to a rotorcraft impacting a flat, hard landing surface at 5 FPS (ultimate) vertical rate of descent. The load factor derived for each unique design is a function of the rotorcraft impact/crushing characteristics.

(ii) The 4.0g down load factor case is related to either a fixed or retractable gear rotorcraft. This condition is not dependent on impact characteristics of the rotorcraft.

(iii) As noted in paragraph b(3) above, the design landing load factors may exceed each of the two previous cases and would then become the prominent design (vertical load) parameter for seats, transmissions, fire extinguishers, and so forth.

(5) Items of mass such as fire extinguishers, radio equipment, life rafts, engines, and/or transmissions must be restrained for the appropriate load factors.

(6) Cargo/baggage compartments separated from the passenger compartment must be designed for load factors specified in § 29.787. The conditions in § 29.561 are excepted from that standard.

(7) Each fuel tank and its installation are subject to the loads stated in this standard whether "under floor" or located elsewhere. (See § 29.963(b) also.) Under-floor fuel tanks are specifically addressed in § 29.561(d); however, an acceptable means of compliance with CAR 7.261 which is identical to and preceded § 29.561(d) is quoted here for information.

> NOTE: Fuselage keels whose design and structural strength are such as to resist crash impacts associated with the emergency landing conditions of § 7.260 (§ 29.561) without extreme distortion which might tend to rupture the fuel tank may be considered to comply with the requirements of this section (7.261).
>
> Puncture resistant "bladder" fuel cells that are adequately designed and also protected from the stated impact loads imposed on the fuselage may also satisfy the standards.

(8) For rotorcraft with retractable landing gear, alternative landing gear positions and the resulting effects on potential fuel release should be evaluated.

AC 29.561A. § 29.561 (Amendment 29-29) EMERGENCY LANDING CONDITIONS -GENERAL.

a. Explanation. Amendment 29-29 adds or increases the design static load factors of § 29.561 in three different areas. The addition of these load factors eliminates the 5 FPS descent velocity criteria of unamended § 29.561(b)(3).

(1) The design static load factors for the cabin in § 29.561(b)(3) are increased in concert with the dynamic test requirements of new § 29.562.

(2) Design static load factors are added in § 29.561(c) for external items of mass located above and/or behind the crew and passenger compartment.

(3) The static load factors, which were formerly only referenced in § 29.561(d), are now included explicitly in § 29.561(d) for substantiation of internal fuel tanks which are below the passenger floor.

b. Procedures. The procedures of paragraph AC 29.561 continue to apply except the new load factors of § 29.561 should be used. Penetration of any items of mass into the cabin or occupied areas should be prevented. In addition, each fuel tank and its installation are subject to specific load factors that are based on the fuel tank location.

(1) The crash impact load factors for the airframe structure surrounding the underfloor fuel tanks are specified in § 29.561(d). The fuselage structure must be designed to resist the specified crash impact loads and to help protect the fuel tank from rupture. If equipped with retractable landing gear, the effects of the landing gear

on fuel system rupture should be considered in both the retracted and unretracted configurations.

(2) Section 29.952(b) (see AC 29.952) specifies the design load factors for crash resistant fuel systems in an otherwise survivable impact. This section relates to § 29.561(d) as follows. The § 29.952 load factors are for the fuel tanks, other significant mass items in the fuel system, and their attachment to the rotorcraft airframe for both occupant survivability and retention of fuel in a survivable impact; whereas, the § 29.561(d) load factors only apply to the rotorcraft airframe surrounding the underfloor fuel tanks and their installation for the same reasons. These two sets of load factors are not additive. They are applied separately (as design ultimate load factors) to the portions of the rotorcraft to which they are specified to apply. The application of the § 29.561(d) load factors is described as follows. The loads generated by § 29.561(d) are intended to be applied to the airframe structure surrounding the fuel cell to ensure that the entire airframe structure provides the appropriate level of crash resistance (i.e., stiffness, crushability, crushing rate, energy absorption capability, etc.) and to ensure that the airframe structure's failure modes (e.g., buckling, creation of sharp edges, structural spears, etc.) are such that fuel cell rupture (and the resultant post crash fire potential) is mitigated to the maximum practicable extent in a otherwise survivable emergency landing. Each fuel cell (and major fuel cell component) creates an applied load on the airframe in an emergency landing condition. These loads are determined by multiplying the worst case mass of the fuel cell (i.e., a full fuel cell) by the load factors of § 29.561(d). These loads are then applied (utilizing the appropriate design load paths) to the airframe structure surrounding the fuel cell to help design the structure for optimal crash resistance. Added stiffness effects for both a full and less than full fuel cell should be considered in the design process. A significantly less than full fuel cell will typically not have any significant stiffness effects, since in a less than full condition the fuel cell cannot typically transfer load hydraulically.

AC 29.561B. § 29.561 (Amendment 29-38) EMERGENCY LANDING CONDITIONS-GENERAL.

a. Explanation. Amendment 29-38 adds a new rearward emergency load factor of 1.5g to both §§ 29.561(b)(3)(v) and 29.561(c)(5). The addition of the 1.5g rearward load factor in § 29.561(b)(3)(v) is to provide an aft ultimate load condition for substantiation of the restraints required for retention of both occupants and significant items of mass inside the cabin that could otherwise come loose and cause injuries in an emergency landing. The addition of the 1.5g rearward load factor to § 29.561(c)(5) is to provide an aft ultimate load condition for substantiation of the support structure for retention of significant items of mass above and forward of the occupied volume(s) of the rotorcraft that could otherwise come loose and injure an occupant in an emergency landing. Amendment 29-38 also increases the forward, sideward, and downward emergency load factors of § 29.561(c)(2), (c)(3), and (c)(4), respectively, for retention of items of mass above and behind the occupied volume(s) that could otherwise come loose and injure an occupant in an emergency landing.

b. Procedures. The procedures of paragraphs AC 29.561 and AC 29.561A continue to apply except the newly specified load factors must be used. A list of the significant items of mass to be considered should be compiled by the applicant and approved by the certifying authority.

AC 29.562. § 29.562 EMERGENCY LANDING DYNAMIC CONDITIONS.

a. Explanation. Amendment 29-29 adds new requirements for the dynamic testing of all seats in rotorcraft.

b. Procedures. AC 20-137, "Dynamic Evaluation of Seat Restraint Systems and Occupant Restraint for Rotorcraft (Normal and Transport)," provides procedures for complying with § 29. 562 using the 170-pound anthropomorphic test dummy specified in § 29.562(b). Those seats not occupied for takeoff and landing, and so placarded and identified in the rotorcraft flight manual (RFM), may be excluded from compliance.

AC 29.563. § 29.563 (Amendment 29-12) STRUCTURAL DITCHING PROVISIONS.

a. Explanation. Amendment 29-12 included certification requirements for ditching approvals. The rotorcraft must be able to sustain an emergency landing in water as prescribed by § 29.801(e).

b. Procedures. Refer to paragraph AC 29.801, § 29.801, for procedures.

AC 29.563A. § 29.563 (Amendment 29-30) STRUCTURAL DITCHING PROVISIONS.

a. Explanation. Amendment 29-30 added specific structural conditions to be considered to support the overall ditching requirements of § 29.801. These conditions are to be applied to rotorcraft for which over-water operations and associated ditching approvals are requested.

(1) The forward speed landing conditions are specified as:

(i) The rotorcraft should contact the most critical wave for reasonable, probable water conditions in the likely pitch, roll, and yaw attitudes.

(ii) The forward velocity relative to wave surface should be in a range of 0 to 30 knots with a vertical descent rate of not less than 5 FPS relative to the mean water surface.

NOTE: A forward velocity of less than 30 knots may be used for multiengine rotorcraft if it can be demonstrated that the forward velocity selected would not be exceeded in a normal one-engine-out touchdown.

(iii) Rotor lift of not more than two-thirds of the design maximum weight may be used to act through the CG throughout the landing impact.

(2) For floats fixed or deployed before water contact, the auxiliary or emergency float conditions are specified in § 29.563(b)(i). Loads for a fully immersed float should be applied (unless it is shown that full immersion is unlikely). If full immersion is unlikely, loads resulting from restoring moments are specified for sidewind and unsymmetrical rotorcraft landing.

(3) Floats deployed after water contact are normally considered fully immersed during and after full inflation. An exception would be when the inflation interval is long enough that full immersion of the inflated floats does not occur; e.g., deceleration of the rotorcraft during water impact and natural buoyancy of the hull prevent full immersion loads on the fully inflated floats.

b. Procedures.

(1) The rotorcraft support structure, structure-float attachments, and floats should be substantiated for rational limit and ultimate ditching loads.

(2) The most severe wave heights for which approval is desired are to be considered. A minimum of Sea State 4 condition wave heights should be considered (reference paragraph AC 29.801 (§ 29.801) for a description of Sea State 4 conditions).

(3) The landing structural design consideration should be based on water impact with a rotor lift of not more than two-thirds of the maximum design weight acting through the center of gravity under the following conditions:

(i) Forward velocities of 0 to 30 knots (or a reduced maximum forward velocity if it can be demonstrated that a lower maximum velocity would not be exceeded in a normal one-engine-out landing).

(ii) The rotorcraft pitch attitude that would reasonably be expected to occur in service. Autorotation flight tests or one-engine-inoperative flight tests, as applicable, should be used to confirm the attitude selected. This information should be included in the Type Inspection Report.

(iii) Likely roll and yaw attitudes.

(iv) Vertical descent velocity of 5 FPS or greater.

(4) Landing load factors and water load distribution may be determined by water drop tests or analysis based on tests.

(5) Auxiliary or emergency float loads should be determined by full immersion or the use of restoring moments required to react upsetting moments caused by

sidewind, asymmetrical rotorcraft landing, water wave action, rotorcraft inertia, and probable structure damage and punctures considered under § 29.801. Auxiliary or emergency float loads may be determined by tests or analysis based on tests.

(6) Floats deployed after initial water contact are required to be substantiated by tests or analysis for the specified immersion loads (same as for (5) above and for the specified combined vertical and drag loads).

SUBPART C - STRENGTH REQUIREMENTS

FATIGUE EVALUATION

AC 29.571. § 29.571 FATIGUE EVALUATION OF FLIGHT STRUCTURE.

a. Explanation. An evaluation is required to assure structural reliability of the rotorcraft in flight. Advisory Circular 20-95 contains background information and acceptable means of compliance with the requirements. A safe life may be assigned or the structure may be fail safe as prescribed.

b. Procedures.

(1) The fatigue evaluation requires consideration of the following factors:

(i) Identification of the structure/components to be considered.

(ii) The stress during operating conditions.

(iii) The operating spectrum or frequency of occurrence.

(iv) Fatigue strength, and/or fatigue crack propagation characteristics, residual strength of the cracked structure.

(2) Since the design limits, e.g., rotor RPM (maximum and minimum), airspeed, and blade angles (thrust, weight, etc.) affect the fatigue life of the rotor system, it is necessary that flight conditions be conducted at limits that are appropriate for the particular rotorcraft and at the correct combination of these limits. It will be the responsibility of flight test personnel to determine that the flight strain program includes conditions of flight at the various combinations of rotor RPM, airspeed, thrust, etc., that will be representative of the limits used in service. The flight test personnel should assure that the severity of the maneuvers to be investigated is such that actual service use will not be more severe. Flight test verification may be achieved through:

(i) Flying a representative set of maneuvers with the applicant's pilot in the test aircraft at noncritical combinations of weight, CG, and speed. (An FAA/AUTHORITY letter for specific test authorization would ordinarily be required.)

(ii) Flying a representative set of maneuvers with the applicant's pilot in a similar (certified) model to assess and agree upon the required maneuvers, control deflections, and aircraft rates. The required maneuvers or conditions will be specified in the flight strain program plan.

(iii) Flying a chase aircraft which has a flight envelope appropriate to allow visual confirmation of the proposed and programmed flight maneuvers.

(iv) Observation of telemetered flight data to assure desired control deflections, rates, and aircraft attitudes.

(v) Some combinations of items b(2)(i) through b(2)(iv) above.

(3) Assessing the operation spectrum and the flight loads or strain measurement program will involve airframe, propulsion, and flight test personnel.

(4) Variation in the operating or loading spectrum among models, and variations in the spectrum for a particular model rotorcraft, should be evaluated. AC 20-95, paragraph 7, entitled “Loading Spectrum,” contains the statement that Table 1 (of the circular) contains typical percent of occurrences for various flight conditions for a single-piston-engine powered rotorcraft used in utility operations. In addition, the table should be used only as a guide and should be modified as necessary for each particular rotorcraft design.

(5) The difference in loading spectrum for different models that may be anticipated is illustrated by comparing the percentage of time assigned to level flight conditions, specifically 0.8 V_H to 1.0 V_H for three different rotorcraft designs where V_H is the maximum airspeed at maximum continuous power in level flight. The first was obtained from Table 1, AC 20-95 which applies to a single-piston-engine powered small rotorcraft used in utility operations. The second was obtained from data for a single-turbine-engine powered seven-place small business and utility rotorcraft. The third was obtained from data for a twin-engine-powered 13 passenger transport rotorcraft. It should be noted that the level flight percentage of occurrences shown in the table below for the turbine utility business and twin turbine transport rotorcraft are only examples of a particular design. The high percentage of time shown in this flight regime could be unconservative for some designs, especially if the stresses under these design conditions produce an infinite fatigue life for the particular component. The fatigue spectrum percentage of occurrences in AC 20-95 may be modified according to the intended operational usage of the rotorcraft. However, a conservative application should be considered.

FIGURE AC 29.571-1

Comparison Percent of Time in Level Flight

Piston Utility		Turbine Utility Business		Twin Turbine Transport	
0.8 V_{NE}	25%	0.8 V_H	16%	0.8 V_H	15%
1.0 V_H	15%	0.9 V_H	21%	0.9 V_H	20%
1.0 V_{NE}	3%	1.0 V_H	24%	1.0 V_H	38%
Total	43%		61%		73%

This variation illustrates the “tailoring” of the loading spectrum for the type of rotorcraft and the anticipated usage.

(6) External cargo operations are a unique and demanding operation. A “logging” operator may use 50 maximum power applications per flight hour to move logs from a cutting site to a hauling site. Power is used to accelerate, decelerate, or hover prior to load release. Lifting loads over an obstruction or natural barrier is another example of very frequent high power applications for takeoff and for hovering over the release area. Similar types of operations require flight loads data to assess the effects on fatigue critical components.

(7) Frequently the applicant may request approval of a gross weight for an external cargo configuration that exceeds the standard configuration gross weight. The external cargo V_{NE} is typically significantly lower than the standard configuration V_{NE} possibly due to adverse effects on flight loads at the increased weight.

(8) The impact of the external cargo operation on standard configuration limits should be assessed to determine whether or not the component service lives will be affected. The assessment may be done by calculating an “external cargo configuration” service life for each critical component. The lowest service life obtained from standard configuration flight loads data and loading spectrum, or from external cargo configuration flight loads data and loading spectrum is generally the approved service life. This procedure avoids prorating the operating time between the two types of operations. This procedure is necessary since the regulatory maintenance and operating rules do not require recording time in service for the different types of operations.

(9) The applicant should plan to conduct a flight loads survey program for both a standard configuration and an external cargo configuration, if appropriate. This procedure will avoid delays associated with reinstallation and calibration of equipment.

AC 29.571A. §29.571 (Amendment 29-28) FATIGUE EVALUATION OF STRUCTURE.

a. Explanation. Amendment 29-28 adds a requirement to substantiate tolerance to flaws during the fatigue evaluation of structure. A flaw tolerant safe-life evaluation or a fail-safe (residual strength after flaw growth) evaluation is required by § 29.571(b) unless “the applicant establishes that these fatigue flaw tolerant methods for a particular structure cannot be achieved within the limitations of geometry, inspectability, and good design practices.”

b. Procedures.

(1) AC 29 MG 11 provides acceptable general procedures for complying with Amendment 29-28.

(2) Specific rotorcraft drive system gear fatigue evaluation procedures, which supplement Appendix 1, follow:

(i) Fatigue test evidence is necessary for the fatigue evaluation of gears. The test evidence should be provided by rotating tests of complete gearbox specimens operating under power. The tests provide the basis for analysis leading to the establishment of safe-life.

(ii) The tests are conducted specifically for the purpose of gear tooth evaluation, and components subjected to the tests do not have to be considered serviceable on completion of the test. Excessive wear on bearings and shafts and marking (including spalling) of bearings and gear teeth are acceptable provided no fatigue damage is evident on the gear teeth. However, fatigue damage other than tooth fatigue should be considered for test validity and the integrity of the affected part confirmed as necessary.

(iii) The test conditions (torque versus number of cycles) should permit the setting of mean strength curve(s) to be associated with each primary gear in the drive train. The minimum test condition should encompass those power levels for which repeated application in service is expected under normal conditions. The S-n curve(s), for the material and type of gear, should be reduced by a factor of safety to take into account material and manufacturing variability. The factored curve will then be used in conjunction with the flight power spectrum to determine a life (limited or unlimited) for the gears in the primary drive system.

(iv) Special procedures, which do not affect fatigue evaluation of the gear teeth, may be allowed to facilitate completion of the test provided they have been justified and they do not affect life determination. These include periodic interruption for inspection, replacement of non-critical parts and the use of special lubricants, special cooling systems, and methods to prevent unrepresentative deflections at the test torque levels.

(v) From evidence in relation to the strength of steel gears of conventional design, it is accepted that adequate fatigue strength can be demonstrated by the use of the above safety factor of 1.4 for a single test, 1.35 for two tests, 1.32 for three tests, and 1.3 for four or more tests. Where several tests are to be conducted, specimens should be selected from different manufacturing batches if practicable.

(vi) Demonstration of infinite life for gear teeth will normally require tests of a minimum of 10^7 cycles duration at factored power levels. Use of shorter duration tests should be justified.